Artificial Agents Modeling for Intimate Telepresence

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ARTIFICIAL AGENTS MODELING FOR INTIMATE TELEPRESENCE

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Declaration

I hereby declare that the thesis is my original work and has been written by me in its entirely . I have duly acknowledged all the sources that have been used in the thesis.

This thesis has also not been submitted for any degree in any university previously.

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Abstract

Telepresence refers to a set of technologies which facilitates illusive presence or illusion of non-mediation, to give the sensation of being present, or to have an effect, through telerobotics, at a remote location [1]. This requires providing the user's senses with stimuli from remote locations and enables them to affect the remote location. Additionally, it involves sensing, transmitting and duplicating the user's behaviors, status, voice, nonverbal cues, context, and other subtle cues at the remote location. Intimate telepresence or mediated intimacy refers to a group of telepresence technologies which convey the illusion of being co-present with the intimate partner or loved ones. Intimate presence in face to face communication requires the physical and emotional closeness. Therefore to support intimate telepresence researchers in this field have taken two approaches of "mediating intimate behaviors" and "provoking intimate reactions", which were inspired by the emulation of co-located intimate behaviors between couples.

Although, the field of intimate telepresence is largely populated by technologies that are designed to emulate the co-located behaviors, there are still some unexplored problems that require more research. One important issue during communicating through current telepresence technologies is the need for simul-

taneous availability of both interacting parties, which is not always possible due to the contextual differences (e.g., location of partners, time zone differences, people around). This opposes to the need for ongoing connectedness in intimate communications [2]. In this dissertation a new generation of telepresence technology that increases the possibility of ongoing connectedness, self-disclosure, and empathy through stochastic detection of the user's mood state and regenerating it in the remote location is presented. The model also allows generating natural, empathetic reaction to the mood state of the remote partner via the other partner's artificial agent. This Artificial Intelligence (AI) model serves as the control mechanism of our offered intimate telepresence agent.

Apart from the AI module and the control mechanism of the intimate telepresence agent, there are also some unexplored problems in the user interface or the medium of the interaction. One overlooked issue in mediated intimate telepresence technologies is the issue of physical embodiment. Despite the importance of embodiment and its influence in the perception of co-presence, technologies developed to date for this purpose are relatively abstract. To the best of our knowledge, adoption of embodied humanoid robots as the medium of interaction for intimate telepresence is unexplored. In this dissertation we designed, developed and evaluated a pair of personalizable telerobotics technologies for intimate telepresence. These robots can transmit the body languages in the remote location and are designed based on the concepts of embodied and enclothed cognition (explained in 4.2.3 and 4.2.2)and the influences of appearance and likeness on affectivity.

Another issue addressed in this thesis in relation to the medium of the interaction is transmitting the intimate behavior of kiss. Intimate behavior of kiss despite its importance in intimate communications is still not well supported by the conventional communication media. In this dissertation a pair of robotic interface for transmitting kisses is developed through iterative design practices. The final prototype is evaluated during a field and a long term user study in participants daily life, which led to the design insight for this category of telepresence technologies.

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Dedication

To:

My dear parents for their everlasting love and support;

My caring and supportive brother Dr. Omid;

My loving sister Azadeh

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Chapter 1

Introduction

This dissertation attempts to take steps to facilitate remote, intimate interactions by means of artificial telepresence agents. The focus of the study is on the design and development of artificial agents, including humanoid telepresence robots, abstract robotic interfaces, and artificial character on Smartphone.

1.1 Motivation and background of the study

Due to improvements in telecommunication technology, which facilitate varied methods of communication across the world and ease of travel, long distance relationships are on the rise. Even some married couples across the world are involved in a Long Distance Relationships (LDRs) due to environmental and economic factors such as military deployment, studying abroad, and increased opportunities to involve in overseas jobs.

In order to facilitate and maintain the relationship, commonly remote communication tools like email, phone calls, online texts, audio and video chat are adapted for LDR. Mediators of human remote interactions are particularly essential for people living apart and for partners involved in long distance, romantic relationships. However, due to the fact that they were invented primarily for efficient communication in the workplace [9, 10] and support task oriented activities, such as collaboration and coordination [11], they are impersonal, generic and emotionally poor. Conventional media technologies are handling multimedia, informative, logical communications based on logic and targeting the user's perceiving the message [12]. Even social networks, which have gone beyond only communicating logical information and can also facilitate socialization, still fall short of intimate communication. Therefore, these tools might not fully address the remote lovers' emotional needs and encourage intimate interactions.

Intimacy is of central importance in enduring romantic relationships; the level of it exerts a profound influence on attainment of marital happiness [13], and even health and well-being [14]. Experiencing intimacy has been identified as a factor that helps individuals to maintain their physical and mental health [15]. Failure to obtain satisfactory levels of intimacy in a romantic relationship has been the most frequent reason given by couples for their divorce [16]. Humans have considerable social and personal needs to feel intimate and connected [17]. Intimacy creates tight emotional bonds that maintain close connections. Cheal [18] suggested that intimacy can be seen as a reminder of the fact that "each other is indeed significant", because an intimate relationship always consists of a private world of significant others.

In this regard, there has been a movement from efficiency to affectivity in the study of intimacy within the human-computer interaction (HCI) community [19]. A growing number of studies attempted to develop affective technologies specifically for mediating intimacy [20]. These technologies are categorized under *phatic technologies*. It refers to the technologies that are not aiming to exchange any particular thought or facts about the world; they, however, focus on strengthening intimate bonds and establish and maintain the possibility of communication [21].

Richness of mediated environment or supporting phatic interactions, in the context of our research, refers to the communication protocol that enables the medium to carry non-informative, experience oriented aspects of communication, which are limited in the current mediated communications, while carrying informative ones. Researchers in this area tried to revive the affective notions by restoring the missed signals.

In a study by Gooch and Watts it is argued that social presence has direct impact on feeling of closeness in personal relationships [22]. In their study it is demonstrated that, development of technologies that support emotionally significant communication experiences, the relationship is supported in a more meaningful, long-term fashion by facilitating feelings of Closeness. According to the social presence theory [23], substantial social context cues commonly available in face-to-face communication are absent in computer mediated communication. If these signals become attainable through the communication medium, interaction parties might achieve higher perception of closeness. Therefore, reproduction of social presence cues might reduce the icy perception of remote communication and make it more personable. In other words, social presence describes the sensation of co-location with another intelligent being or the perceived sense of warmth and sociability provided by a medium. It can declare the degree of similarity between face-to-face and mediated interactions [24].

Sense of presence is defined as a multi-component and subjective notion [25] which is accomplished when the person has the feeling of truly being present in a distant environment. Shen and Khalifa suggested three dimensions of social presence for remote online interactions as awareness, cognitive social presence, and affective social presence [26]. Awareness refers to the user's cognizance of the presence of other social entities. Cognitive social presence argues constructing and confirming the user's social relationship with others; and affective social presence associates to the user's emotional relation with others. Yet simple awareness of the presence of others is a prerequisite of user's perceptions of cognitive and affective social presence.

1.2 Research questions and research problems

Having an overall goal of phatic technologies as *strengthening intimate bonds* and *establishing and maintaining the possibility of communication* in distant communication in mind, this dissertation, is initiated by the initial research question as:

"How to facilitate intimate communication across distance by means of novel interactive telepresence technologies."

This initial research question is used as the starting point to explore the state of the art in this area. After, a comprehensive literature review under the umbrella of this broad question, future research directions are revealed and among them three sub-topics are explored.

The design space in intimate computing technologies is largely populated with prototypes and artifacts that targeted affectivity in telepresence. Next chapter (2) describes a detailed description of the previous works in this area. Despite, the large variety of the attempts in this area, there are still plenty of unaddressed issues. In the last section of the following chapter as: 2.6, a brief description of these problems in our perspective are pointed briefly and among them three main problems are explored in this dissertation.

By reviewing the previous studies, it was noticed that firstly:

Problem 1: Current developed technologies for mediating intimacy are limited in terms of embodiment

If we divide these technologies to two classes of virtual and physical interfaces it can be seen that: The category of virtual interfaces, regardless of their degree of holism, they lack the tangibility. Therefore, they are limited in terms of spatial dimensions, haptic communication and space sharing. Therefore, the virtual media might not be the ideal platform for mediating intimacy. Another category of these technologies includes tangible and physical interfaces. However, the developed interfaces in this category are rather abstract and are limited in anthropomorphic features. [1] Therefore, nonverbal signals related to body languages and human emotions are filtered in this class of intimate computing technologies.

Both physicalness and anthropomorphic nonverbal cues are very crucial in providing the illusive presence with the intimate partner which are not fully conveyed in current prototypes. To the best of our knowledge, despite the potential of humanoid telepresence robots in teleporting nonverbal cues related to anthromorphism, humanoid telepresence technologies are not explored for intimate telepresence.

To restore the perception of presence, some researchers have focused on stimulation of senses such as tactile sense [27],[28],[29],[30],[31]; smell and taste transition [32][33]; visual cues and augmented environments [34],[35]; real-timeness

[1] Anthropomorphism, or personification, is attribution of human form or other characteristics to anything other than a human being.

[36]; spatial audio[37]; and sensory replacement to overcome personal or technological limitations, or enriching the experiment [38],[39]. All the above parameters trigger the sense of presence to some extent. However, it seems that they lack the complete vividness and interactivity defined by Steuer [40], since these technologies do not provide the desired embodied and immersive interactions.

Affective social presence is highly influenced by media attributes. Gibson [41] suggested that perceptual parameters help to create this sense. Steuer describes the notion of telepresence as “the experience of presence in an environment by means of a communication medium” [40], denoting vividness and interactivity as the basis of telepresence. Vividness points to the ability of a technology to generate a sensorial rich environment. While interactivity points to the degree to which the users can affect the form or essence of the mediated environment [40]. Although the focus of Steuer’s argument was particularly geared towards the virtual reality technology, it sparks the idea of considering the robots as a medium of affective communication. Two notions of embodiment and immersion, which correspond to vividness and interactivity respectively might be enhanced through the medium of telepresence robots.

Vividness points to the sensorial richness of a specific mediated environment. Robots can be looked into from two different points of view of appearance and spatiality along this dimension. Taking into account aesthetic attributes of the medium, robots are relatively rudimentary compared to graphically rich virtual avatars. On the contrary, they benefit from the advantage of being movable in 3D, beyond the confinement of the screen of monitors and 2D context; and coexist in the same realm that the viewer lives [42]. This can be compared to live performance and watching a high resolution, graphically advanced movie which despite its technologically advanced features lacks the emotional warmth. This issue becomes more salient when it comes to interpersonal and affective communication in which emotional attributes become influential. In these scenarios, users are more likely to need something that can be touched, shows a comprehensive range of nonverbal and emotional behaviors and coexists in close proximity. This can be seen as a radical departure from the rigid screens to the real world.

The second feature that plays a significant role in the richness of mediated environment is interactivity which has a direct relationship with the concept of immersion and is about the participation and feedback from the medium or mediated environment. Immersion corresponds to the degree of involvement the user experiences [43] which is described by the degree with which a user is fully engaged in the environment. Ideal immersive experience is achieved when environments at both ends are remarkably controlled and are replicated as similar as possible with respect to illumination, acoustics, decoration and even furniture (e.g., Cisco's Telepresence rooms). Such an arrangement leads to an illusive sensation that both users are together at the same table in the same room, thus creating the immersive interaction. Although advanced audio and computer graphic technology and artificial intelligence can efficiently engage the user and convey the illusion that the user is in the mediated environment, telepresence robot (the surrogate of the remote person) and the local user really exist in the same context and physical space. The interactivity itself is implemented by replicating body languages and appearance of the absent partner in this study.

We believe since robots provide vividness by their holistic and physical nature and enrich immersive experience due to their existence in the realm of the user, they have the potential to provide a rich channel for interpersonal communication. Although, their limitations in terms of degrees of freedom and development costs compared to virtual environments is acknowledged and therefore there is a trade-off in the choice of virtual or physical embodied agents depending on the context. But, still due to the potentials of physical humanoid robots in communicating intimacy they are worth being studied. This problem is explored in chapter 4 of this thesis

The second problem explored in this study is in relation to physical intimacy in LDR (6). To emulate the physical intimacy across distance, several prototypes have been proposed. The common design theme in these studies is transmitting the nonverbal signals that are felt during the close body contact. Design perspective of this type of telepresence includes: teleporting biological signals such as heartbeats, body temperature, pressure or force or the whole intimate gestures such as hugs. In chapter 2 section 2.5.1, these technologies are described in detail. It was noticed that, very few studies have focused on teleporting the intimate behavior of kisses. Moreover, studies in this area are relatively limited in terms of empirical user evaluations and design stage. In practice, in current conventional communication media it could be only transmitted symbolically using the emoticons. Therefore:

Problem 2: There is a need for development and in depth analysis of telepresence technology for communication of the kiss

Positive physical touch is a primary nonverbal intimate cue that enhances psychological immediacy and attraction between people. Kisses are not an exception. Kissing has been the cross-cultural foundation of romantic relationships throughout the ages. It is a fundamental expression of desire, intimacy, adoration and passion for ones romantic partner [44]. Although, in LDR due to the separation of physical space, this essential need cannot be fulfilled. Hence, it is important to facilitate kissing in mediated environment.

The third noticed research problem is related to *ongoing connectedness* in LDR. As explained before, one of the aims of phatic technologies is maximizing the possibility of connection. Generally bidirectional, real-time interaction is only possible when both communication parties are available. Since, in LDR time and contexts [2] are different, the chance of availability of both partners is reduced. For instance, it might be midnight in the geographical location of one partner, while

[2]Contexts in this study refers to the situation that the interaction happens or is supposed to happen

the other partner is interested to communicate. Another example is the situation when one of them is busy and the other one is idle and wants to interact. This opposes to the need of ongoing connectedness, which is even more salient in LDRs. Therefore, the third problem explored in this study in chapter (5)is:

Problem 3: There is a need for facilitating ongoing connectedness in LDR

The ubiquitous technologies with the goal of *ongoing connectedness* is very close to the awareness systems, however there is a subtle difference between them. In a "content-oriented communication" focus is on the exchange of information, whereas in *connectedness-oriented* communication, maintaining relationships and fostering a sense of connectedness is the core of the interaction [45].

In a situation that awareness system has the main goal of maintaining the human relationships and sustaining strong tie relations, the benefits may come not solely from sharing of awareness information, *but more from the simple act of mutual exchange* [21].

The ubiquitous technologies are often developed for information oriented purposes. Such as those coping with aspects of an environment (e.g. navigation systems), those assisting in time and resources management (e.g. diaries and personal sensors), and those inferring situational opportunities for personal purposes (e.g. Context aware systems) or those that display location information or health status (e.g. personal Digital Assistance technologies) [2]. However, these are rarely used to sustain relationship ties.

Due to the priority of possibility of the connection over the content of the interaction, this dissertation aims to develop a control mechanism of a probabilistic behavior generator for telepresence agents. This model could maximize the connectedness by maintaining the interaction while users are not simultaneously available. This problem is addressed in chapter 5 of this thesis.

1.3 Objectives of the research

Attempting to take steps towards the futuristic aim of teleporting the physical presence of an intimate partner this dissertation has addressed the following objectives:

- Explored the design specification of humanoid, physical telepresence agent for LDR, through technological probes [3].
- Design, development, quantitative and qualitative analysis of telepresence agents for mediated kiss.
- Modeling affective telepresence agents, AI module for control of the agent's behavior, based on the estimated probabilistic mood state.

[3] "Technological probes are simple, flexible, adaptable technologies, which their design goal is inspiring users and designers to think about new technologies." Use of technology probes as the research instrument is an established design methodology, which were first introduced in [46]

1.4 Contribution of the thesis

- A comprehensive survey of the state of the art in intimate computing and suggestions for potential research directions.
- Minimal prototyping of personalized telepresence robots, as the basic platform for mediator of remote partner's presence.
- A design insight for development of humanoid surrogate telepresence robots with LDR application.
- Demonstrated the level of effectiveness of embodied media personalization on the perceived affectivity of interaction through user studies, and conceptual explorations.
- Iterative design and prototyping of a haptic telepresence system with the ability to sense and reproduce kisses between two remotely located users.
- Providing the first in the field and timely evaluation of intimate telepresence technologies, with the focus on teleporting kiss, with the real LDR couples.
- Introducing a novel approach for smart control of the artificial telepresence agent. The model could automatically produce behaviors on behalf of each user, based on their probabilistic mood state.

The whole study has targeted couples in LDRs, however, it also could be extended to other mediated intimate interactions such as parents and babies, when they are apart.

1.5 Scope of the study

The thesis has focused on three different aspects of intimacy including cognitive, emotional and physical, separately within LDR. The outputs of each stage could act as a part of a holistic telepresence system in its ideal form, however integration of this three as one telepresence system is not within the scope of the study. Also, all the participatory designs and evaluations are conducted with heterosexual couples. The focus of this dissertation is mainly introducing new media and novel methods of interactions with less emphasize on optimizations and high fidelity development.

1.6 Thesis outline

This thesis is organized as follows. Chapter one is the introduction of the study. In chapter 2 a classified survey of the state of the art in intimate computing is presented. Chapter 3 describes the methodology and study procedure. Chapter 4,5, and 6 describe different stages of the modeling. In which chapter 4 explains the study on intimate telepresence through physical agent, chapter 5 describes modeling smart affective telepresence agent, and chapter 6 explains modeling agents for haptic telepresence. Chapter 7 presents the conclusions and directions for further studies.

Chapter 2

Literature Review

2.1 Introduction

As the objective of the research is mediating intimacy, a clearer understanding of intimacy is important. The reason is, it provides the basis for the development of artifacts and interfaces that better support remote intimate relationship. This review is divided into two parts: including clarification of the concept of intimacy and review of interactive intimate computing research works to date.

The first part presents a theoretical discussion of the prominent and common themes and concepts found throughout the intimacy research literature in social science and HCI. This includes: physical intimacy, cognitive intimacy, affective intimacy, self-disclosure, mutuality, commitment and closeness. Further, some special issues of LDRs are highlighted to indicate the challenge of satisfying their intimacy. The intimacy review is able to provide a framework or 'lens' for conducting the empirical research of intimate interactions between LDRs. It will serve as guidelines for the development of interactive technologies evaluations and refinements in the following chapters.

The second part explores how intimate computing research and interactive technologies support romantic relationship, with a particular focus on LDRs. In addition, a selection of recent prototypes and exploratory interactive technologies that attempt to mediate close intimacy are reviewed. Several examples of measurement and evaluation of prototypes are involved in the discussion. This part of the chapter is described in more detail because of its potential for inspiring and informing the interactive media development for enhancing the affective experience in sensitive settings.

2.2 Definition and Importance of the Intimacy

Despite the long-term effort on investigating the intimacy from the sociological and psychological researches, the attention from HCI are put in this field of research due to their changing force from efficiency to affectivity in the past few years [47]. In Handbook of closeness and intimacy, it is emphasized that the concept of intimacy is related to the notion that *including other in self*, which can be understood as *double being* or *living in each other's subjective context of meaning* [48]. Intimacy is also defined as "mainly a process of an escalating reciprocity of self-disclosure in which each individual feels his or her innermost self validated, understood, and cared for by the other" [49]. That is, intimacy increases as each learns about and so presumably is able to include the other's perspective [50].

Intimacy is of central importance in enduring romantic relationships, the level of it exerts a profound influence on attainment of marital happiness [51], and even the health and well-being [52]. Experiencing intimacy has been identified as a factor that helps individuals maintain their physical and mental health. Failure to obtain satisfactory levels of intimacy in a romantic relationship has been the largest category of problem behavior which motivates people to obtain outpatient psychotherapy [53] and as the most frequent reason given by couples for their divorce [54].

Common themes in intimacy: While the previous literature provides no unanimous agreement about what an intimate interaction consists of and how it can be presented and understood, some common themes do appear. To understand the construct of intimacy, an extensive, computer-assisted search of scholarly publications and books for definitions of intimacy is conducted by [55]. In their findings, seven themes were found which occurred in at least 50% of definitions as below:

(Th1) Mutuality: Mutuality illustrates the strong sense of reciprocal binding during the intimacy exchange [3]. Mutuality does not necessarily require synchronousness or identical pattern of interaction. Rather, it implies the joint and shared feelings and experience: it has an assumption that intimate partners are co-engaged in a common cause [56]. Mutuality is not limited to the act of interaction itself, but have a wide interpretation within different aspects of the partners' physical and mental experience: for example, in sending each other a goodnight message [57], the preparation and expectation of the recipient (e.g. Lying in bed, looking at the phone frequently) for the incoming message is also regarded as a part of the mutuality [3].

(Th2) Physical intimacy: Physical intimacy is recognized as an essential aspect of intimate interactions [58]. It can be understood as 'physical expression of intimacy' which is the sharing of physical encounters ranging from close physical proximity to sexual contact [3]. Within close relationships, there are often non-verbal, but highly expressive physical contacts like touching and patting to create a sense of closeness and proximity. Physical intimacy is not limited to bodily contacts: it also includes the feelings of new bodily experience (e.g. Butterflies in the stomach) arising from physical contact with the partner and the exchanging of artifacts (e.g. Gifts) which act as a proxy when the partners were distant in space or time [3].

(Th3) Cognitive intimacy: Cognitive intimacy refers to the depth of cognitive understandings of each other in intimate interactions. This includes knowing one another's principles, values, strengths, weaknesses, hopes, fears, internal feelings and idiosyncrasies [59]. During the interaction, intimate partners consciously or/and unconsciously exchange and share a range of personal information and preferences, which will increase the level of intimacy they experienced [60]. The deep cognitive intimacy leads to rich private meanings in the intimate acts which are difficult to see and interpret by outsiders.

(Th4) Affective intimacy: Intimate interactions often contain the exchanging of emotions. The reception and expression of emotion in close relationship are reflected as affective intimacy [61]. In fact, much of the interactions and communications that pass between romantic relationships are more emotional rather than factual: the messages are often information poor, but laden with affective and emotional significance [60]. The level of affective intimacy presents the depth of love, caring, compassion and positive attraction for one another. As a result, it is often viewed as a key factor to distinguish close friendship and real romantic relationship.

(Th5) Commitment A shared commitment and feeling of cohesion is an important foundation for intimate relationships. Being committed, both of the partners will perceive their relationship as ongoing for an indefinite period and any changes in one partner's belief in the commitment of the other may impede the growth of an intimate relationship [62]. Therefore the commitment constitutes a crucial requirement for building and sustaining an intimate relationship.

(Th6) Self-disclosure: In discussing the wide interpretation of intimacy, self-disclosure is described as one of the delineations that are more central than others by [63]. Self-disclosure includes releasing of private information and removing of the boundary between oneself and the partner both physically and psychologically [64]. As it reflects the level of getting inside the life of each other, self-disclosure is frequently used as a measure of intimacy [65].

Two types of self-disclosures are distinguished in intimate relationships: descriptive and evaluative: Descriptive one refers to the disclosure of unknown factual material, e.g. one has two brothers and a sister; Evaluative one refers to the disclosure of subjective feelings or emotions, e.g. one is feeling very angry after an examination failure. Evaluative self-disclosure is seen as more important because of its close connection with affective intimacy in intimate interactions [66]. Further, it is suggested that act of self-disclosure is important if you want to be liked and approved, and always carries with an expectation of reciprocation: it need to be returned in-kind in order to maintain the intimacy and *partner awareness* [67]. Nonetheless, self-disclosure should be matched to the level of relationship: Disclosing too little or too much can either escalate or de-escalate relationships [68].

(Th7) Closeness: In social psychology, closeness is the personal distance between two people. In an intimate relationship, the feeling of closeness is not only due to being physically co-located, but is about the quality of intimate relationship [69]. It relates to the term *presence*, which can be triggered by symbolic actions or representation of the other even when the couples are remote. A strong feeling of closeness contributes greatly to intimacy, leading to the feeling of another person being *present in absence*[70].

It is important to note that these themes are highly interrelated and greatly overlap [71]. They support each other and create the intimate experiences together. For example, a simple kiss between couples at the same time conveys physical intimacy, affective intimacy, and involves mutuality in the whole process.

Intimacy in face-to-face (F2F) and computer mediated communication (CMC): An intimate relationship in F2F communication is particularly close interpersonal relationship that comprises physical or emotional intimacy. Nardi [72] defines three dimensions of *affinity, commitment, and attention* for interpersonal communication. In this definition Affinity compromises all the activities that promote the social bonding inclusive of: touching, eating and drinking together, sharing experience in a common place and informal conversation. Commitment is defined as *simply being there* or co-presence which is best communicated in F2F. And finally attention is captured and monitored through verbal exchanges as well as *eye gaze*.

The other class of interpersonal or its extreme intimate communication is emotional intimacy, which is closely connected to love [73]. Kaye [74] proposed to deal with mediated intimate communication through considering how people express their love. He refers to the popular framework described in a book titled: the Five Love Languages by Gary Chapman [75], which defines five ways of expressing love as, words of affirmation (expressing love in words, quality time), giving dedicated attention, gift giving, acts of service (doing things for the loved one), and physical touch.

In another study Howard et al. [76] counted self-disclosure, presence in absence, informatively poor and emotionally rich, ambiguity and incompleteness, privately constructed and need of strong mutuality as attributes of intimate acts. Considering the lack of any universally accepted definition of intimacy, Vetere et al. [3] performed a qualitative human subject study with couples and suggested a schematic to describe intimacy (see Figure 2.1). It reflects the intimacy attributes before, during and after the experience.

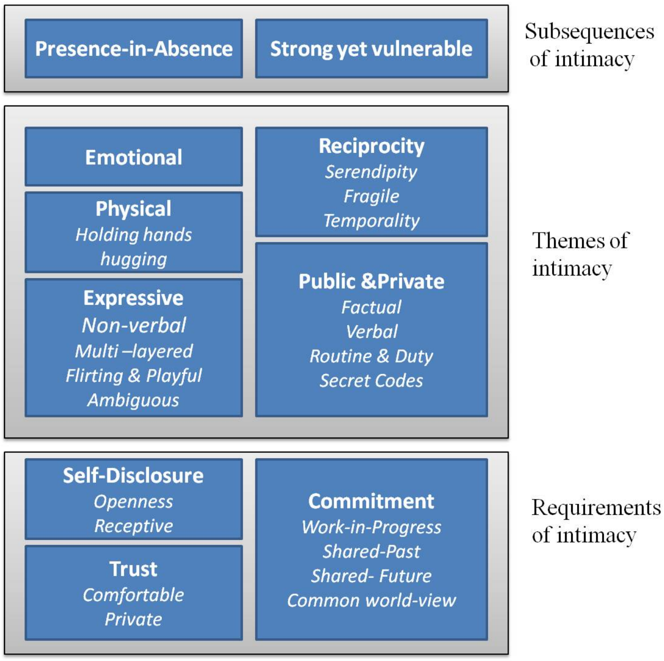

Figure 2.1: Antecedents (requirements), Constituents(Themes) and Yields (Results) of Intimacy [3].

CMC technologies try to facilitate similar connections seen in F2F in remote communications. For instance near body presence is simulated through robotic interfaces, physical mediators as well as transmission of biological signals. Experience sharing is made possible through remotely controlling shared physical or virtual interfaces. Attempts in facilitating emotional intimacy have taken the approach of adding features such as: Ongoing connectedness, serendipity, playfulness, need of effort, individualization, co-creation, coded language and many more related properties to the interfaces.

Interpretation of the intimacy in the context of mediated intimate telepresence Based on the above discussed issue we define intimacy within the scope of telepresence research as:

Intimacy is the perception of closeness to the extent of sharing the physical, emotional and mental intimate space. In the mediated environments, intimacy could point to the illusive near body telepresence as well as discerning the internal affective state of the significant other.

The following sections describe in details all the previous attempts to afford remote intimate communication.

2.3 Intimate Computing

Maintaining intimacy in the relationship is emphasized as a necessary factor of the romantic relationship [77]. Irrespective of whether it is a physical or an emotional intimacy, relationships might slowly die without it. However, increase of Long Distance Relationships (LDR), and poor functionality of the current telecommunication system hampers the convergence of intimacy across distance.

Conventional technologies for mediated remote communication are originally designed for collaboration, teleoperation and task oriented activities which are optimized for efficient exchange of information. This trend compromises the non-informative dimension of interaction. Therefore, intimate computing increasingly gained the attention of Human Computer Interaction (HCI) and Human Robot Interaction (HRI) researchers to support LDR and has opened a new area of study known as *Intimate Computing*. It resulted in a considerable amount of studies and prototypes, by adopting the metaphor of remote or mediated intimacy.

Intimate computing is a subset of affective computing, which ranges from poetic exchanges to complex telepresence robots. It refers to the set of technologies that foster or facilitate forms of interaction between remote people that would normally only be possible if they were co-located [78]. In these technologies the goal is promoting social bond rather than any information or data transition.

In the following sections a survey of the current state-of-the-art in intimate computing is presented. It describes research and prototypes developed to date, and provide suggestions for future directions of research in this area.

2.4 Human factor elicitation for design of intimate medium

Intimate communications are distinct from typical communications studied by HCI researchers, such as relationships amongst friends or colleagues [60]. Challenges of studying intimacy arises from their ephemeral[1] nature [3], low informational content and emotional significant, self-disclosure and privacy, unsaid interactions and idiosyncratic nature. Moreover, designing for intimacy needs, a sensitivity to the notions, structures, and nuances of technology-mediated experiences that are simultaneously perceived by users to be intimate and social [79]. Also, there is no predefined language for its description [80, 76]. Since intimate behaviors are strikingly nuanced and often subtly vague to outsiders, the involvement of users is unavoidable in the design of its supporting technologies. One area of research in intimate computing relates to human factor elicitation and user experience of these technologies.

One of the approaches is using technology probes. Technology probes are flexible and basic technologies with interdisciplinary goals of understanding users needs in the real context, field testing the technology from engineering perspective and inspiring users and researchers for new technology ideas [46]. For example: Lottridge et al. [81] explored the design space for remote, intimate communication between couples. They realized the potential to draw on the daily routine *idle moments* of couples. Ambiguity, aesthetic, continuity, asymmetry, and movability were comforted by users as design space for sharing idle moments.

OB́rien & Mueller [82] applied technology probe to investigate when partners

[1]Gone in a moment and dissolve lightly

in close relationships would want tactile exchange through holding hands while apart. The proposed technology probes were yellow, deformable, hand-size balls that could emulate a tactile experience, similar to holding and squeezing a partners hand. However the experiment was not successful since the probe was too simple to encourage couples to use it. They realized a probe should be simple but aesthetically well designed to encourage participant to use it.

Kaye & Goulding [83] developed personalized probes for long term study through the users proposed sketches. They studied how objects were used and how they changed their communication pattern. This study was based on the advantages of personal over mass communication in the context of intimacy.

Another perspective focuses on scenario based design. For example, Battarbee et al. [58] tried to design for support of intimacy within an urban environment. It was done through observations within the city and developing scenarios. King [76] explored how people use interactive technologies in their relationships through asking the participants to explore the possible future, instead of being restricted to current technology.

Other studies on design space are: King & Forlizzi [84] used interview, web based diary study and photo journal. They found possibilities for emotional connectedness by designing reflective and slow interfaces which are linked to the sense of place. Pace et al. [85] studied virtual world as a source of intimacy and their study suggests four characteristics that describe intimate experience: permeability across virtual and real worlds, the mundane(non-spiritual) as the origin of intimacy, significance of reciprocity and exchange, and formative role temporality in shaping intimate experience.

Gooch & Watts [86] proposed a framework to formalize the design space for intimate communication devices. They have highlighted the six factors of *personalization*, *sensory medium*, *effort*, *openness of the system*, *metaphor of use*, and *fleeting versus realized output*. These factors are based on the study of previous developed devices and more study is needed for validation and refining the framework.

There have been several attempts in exploring the effect of physiological and nonverbal signals on the perception of intimate connections. For instance:

- Mullenbach et al. [87] explored the use of variable friction surface haptic enabled by the TPad Tablet to support affective communication. They concluded that users readily associate haptic with emotional expression and found it well suited for communications with close social partners.
- Carpe Diem [88] explored the effect of eye contact in intimacy by developing a near-eye display video conferencing in which users could merely see one of the eyes of their remote partner. The experiment revealed that the full-screen display of the eye make the discussion more personal, intimate,

close and focused on the moment, by eliminating distractions from the discussion.

- Slovák et al. [89] investigated participant's perception on heart-rate feedback. They found heartrate feedbacks an affective connectedness signal as well as connectors.

- Janssen et al. [90] empirically evaluated the possibility of using heartbeat transition as an intimate signal through self-report and behavioral monitoring in an immersive virtual environment. They found that heartbeat is perceived as an intimate signal in the same way as gaze and interpersonal distance. However, it needs to be attributed to a conversational partner to increase intimacy.

- Gooch & Watts [91] investigated the impact of heat as an aspect of touch using a thermal hug belt. They realized heat can affect the perception of presence significantly.

These are not the only attempts in studying intimate computing through users, however, these are studies dominantly focused on user perception. Other researchers have also involved users in the system design and evaluation into some extents.

2.5 Prototypical systems to mediate intimacy

The design space for remote, intimate couples has largely been populated with technologies that support and mediate intimacy via abstracted presence [92, 93].

Gaver categorized these technologies into two groups, those that mediate intimate behaviors and those which provoke intimate reactions [94]. The first group attempts to mediate intimate feelings or actions through reproduction, manifestation or imitation of them, using technology, whilst the second group concentrates on evoking reactions instead of explicit expressions [95]. Gaver has identified three common features in most of these technologies:

- use of evocative materials
- use of poetic mappings rather than didactic metaphors
- reliance on physical materials.

2.5.1 Technologies that mediate intimate behaviors

In this group often a pair of interfaces, which are coupled together transmit the intimate behavior that requires near body presence. In this approach the interface acts on behalf of the remote person to literally or symbolically reproduce the intimate expressions. In the literal approach the intimate action is directly reproduced, whilst in symbolic (poetic) simulation, intimate behavior is mapped to another form.

Attempts on this category includes different types of remote haptic communications such as hugging, kissing, grasping, shaking hand, hand holding. Other physical interactions such as, whispers, sound of heartbeat and the body heat of the significant others, are in this category.

The following table summarizes the pros and cons of each perspective:

Mapping	Literal	Poetic
Advantage	Natural and similar to real behavior	Triggers emotion and coded language and mapping facilitates privacy in public
Disadvantage	Technical complexity and high possibility of creepy sensation[96]	Perceived feeling is not the same as F2F interaction

Table 2.1: Pros and cons of poetic and literal approaches of mediating intimate behaviors

2.5.1.1 Mediated kiss

Several studies have tried to transmit kisses across distance. *Intimate mobiles* [97] provide direct (real) telepresence through mobile interface. Grasping, kissing and whispering are simulated through pressure sensing, tightness actuation, and human skin heat, infusing the water on a sponge, and airjet respectively. Informal user feedback reflects that the system is perceived creepy and awkward. This study suggests the need for more studies on how people really want telepresence in the future. The opposite approach is *kiss communicator* [98], which is a conceptual prototype that transmits the symbolic representation of kiss by squeezing and blowing the interface. This system facilitates communication in a subtle, sensual way by keeping the nature of the physical object as simple as possible, so the attention is more about the experience of the message. The problem with this system is that, although it facilitates a very sensual feeling it may not be perceived as a kiss.

CheekTouch [99, 100] actuates through a mobile phone. It receives the touch input from multiple fingers and delivers tactile feedback on the remote persons' cheek. It can extend six affective behaviors of pinching, stroking, patting, slapping, kissing and tickling on the phone. It provides hybrid sensory communication through audio and touch which both can trigger emotions. As the system is implemented on a mobile phone, it is good in terms of usability. Although, since the mobile is a device that is used for communication with everyone not specifically with the significant others, it might have reverse effect on the experience of intimacy. And *Hkiss* [101] transfers a kiss from 3D virtual avatars to the real world through haptic stimulation. The haptic stimulation system is very rudimentary both from the design and technical perspective, but enable multisensory interaction through visual cues from avatars.

2.5.1.2 Mediated hug

There has been several attempts in mediating hug. For example: *The Hug* [102] is a telepresence robot that simulates the hug sensation through colored lights, vibration patterns, thermal fibers that radiate warmth, and sounds. It activates when a paired interface is squeezed, or stroked. The hug aims to explore the forms for robotic products that enable remote intimate connection. The association of shape of the interface to the gesture of real behavior is proposed to be supportive of the sense of real hug. This is a visionary prototype without detailed implementation and user feedback.

Hug over a distance [47] is an air-inflatable vest that can be remotely triggered to provoke a feeling resembling a hug. This system supports intimate behavior in public through unobtrusive actuation. *Huggy pajama* [103] allows remote hug through a small hugging device and a wearable, hug reproducing jacket. Hug pressure intensity is sensed through the hugging device and reproduced through the air jacket. The use of air jackets in these two prototypes supports the natural feeling and provides a calming effect similar to a real hug. *HaptiHug* [4] intelligently detects hug keywords from textual messages in Second Life, and then the hug is visualized through avatars in 3D animation and sensed by haptic stimulation (see Figure 2.2). In *Second Life HugMe* [104] 3D virtual avatars and the annotated body parts represent a real user. Virtual avatars receive inputs through gesture, mouse, speech or text based input modalities and produces emotional feedbacks such as touch, tickle and hug to the real user through vibrotactile actuators on the haptic jacket. In these two prototypes visual representation of the partner makes it more similar to the visuo-tactile experience of real-life hug and provides pseudo-haptic illusion. Also, automatic detection facilitates intuitive control of the system.

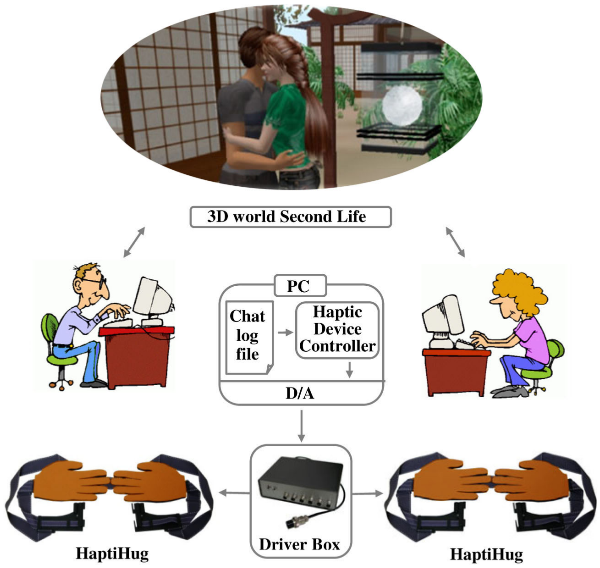

Figure 2.2: Architecture of computer-mediated communication system with hug display [4].

2.5.1.3 Mediated hand-holding, hand-shaking and other intimate hand interactions

There has been several attempts by basing remote communication metaphors on co-located hand-holding and hand-shaking behaviors. *Remote handshaking* has augmented robotic hand on video conference to get the benefits of video-conferencing at the same time that mediates touch [105]. *Tele-handshake* [106] used a phantom force feedback device and a shared virtual interface that allows remote people to shake hands and feel each other simultaneously. Although it is only haptic feedback and the interface does not resemble the form of the hand. *YourGlove, HotHands and HotMits* [107] are three prototypes, in which different sensory mediums of movement and heat are used to present the same metaphor. *YourGlove* [108] is a pair of robotic hands covered by a soft haptic glove designed for hand holding across distance. In this system when one robotic hand is held the other one can grip. Whereas HotHands and HotMits convey the handholding sensation through thermal insulation. All the three prototypes have personalized appearance for each couple instead of a standard shape which supports intimacy through attribution to the user which is done using their hand prints and sleeves (see Figure 2.3).

Figure 2.3: YourGlove, HotHands and HotMits developed for remote hand holding.

Feelybean [109] enables augmenting the hand touching to Skype. It can transmit hand stroke pattern to the remote partner through vibrating motors. *A stroking device while holding hands* [110] allows remote couples to exchange the physical gesture of stroking across distance. The device is designed to touch each other's hands, as well as other parts of the partners' body. The position of the user's thumb is detected by a potentiometer as input gesture which is associated to the output arm position. *The White Stone* [111] extends the sense of touch and presence across distance through the paired stones. The stone detects if someone holds it in the hand, and triggers the corresponding stone to beep and become warm.

VibroBod [112] enables the users to communicate feeling, hand gestures, and vocalizations to the remote user. It rests on the user's lap and detects hand position, pressure and vocalization through force-sensitive resistors and microphone. The associated vibration pattern is transmitted to the remote user. The VibroBod becomes warmer with use, and that warmth, together with the hand holding, hugging pose, convey to users the feeling of holding and being held. All of these prototypes support only a few aspects of real touch and differ from the real experience. There also has been efforts in increasing the realness, for example Avraham et al. [113] tried to afford high fidelity handshake algorithm, combining the best aspects of three algorithms to improve the human likeness of robotic handshake. This is a technical study without consideration of design issues.

2.5.1.4 Mediation of biological signals

WearBEAT and *WearBREATH* are two prototypes that translate biosignals into intimate and implicit information [114]. *WearBEAT* is a body sound sharing device and *WearBREATH* is a breathing movement sharing device. *Mobile Feelings* [115] is an egg-shaped mobile device for remote sharing of heartbeat and breath. Heartbeat and breath are mapped to light-emitting diodes (LED) blinking together with rhythmic pulses and micro-ventilator respectively. *united-pulse* [116] is a pair of rings, whereas each ring can measure the wearer's heartbeat and vibrates the partner's ring accordingly. Paulos [117] provided an interface for exchange of intimacy signals through mapping of force and heartbeat to LED light and vibration. They did not attempt to transmit any predefined intimate action. Instead they allowed users to evolve their own personalized interaction language similar to the approach taken in *ComTouch* [118] interface.

Sensing Beds [119] symbolizes the presence through heat. The position of the bed occupant is tracked through sensors inside the mattress. In five minutes delay, heating pads are activated at the corresponding coordination of the other bed. Their design perspective is slow communication claiming intimacy needs time to grow and flourish.

2.5.1.5 Mediating other gestures and postures

Aura [120] captures sleep patterns of a remote partner using a sensor embedded on a mask, maps them to the form of music and send the data to a personal music box. Its goal is to facilitate the feeling of the remote partner's emotion by listening to the music which is composed from their previous night's sleep pattern. It can support both physical and emotional dimensions of intimacy *Tug n' Talk* [121] remotely transmits tugging as an intimate way of requesting attention, which is a belt-buckle with an attached couple of chains. One chain connects to the users' shirt and the other hangs below the device. Tugs on the bottom chain are transmitted to the associated belt and symbolized as tugs on the chain attached to the shirt itself. It is a simple design idea without consideration of applicability and user testing.

Poke [122] proposed a soft and human-like remote touch technique through an inflatable surface augmented on a mobile phone. It communicates different emotional touches according to the user's finger pressures and hand gestures during a phone call. Inflation patterns and vibrations of the surface deliver different emotional touches. Soft surface and affordance of gestures make it more similar to the natural touch. However, there is no evidence that people really will use them in practice.

Wrigglo [123] is a shape-changing smart phone peripheral that facilitates pairs of users to share wriggling postures with one another. *The ComSlipper* [124], creates the sense of connection to others using a pair of slippers. It communicates the user's emotion sensed from foot postures and tactile manipulations to the remote loved ones. The emotion is received on the remote persons' slipper mapped to vibration, warmth and light. *FootIO* [125] is a footstool like device that can be used when sitting in a chair. It is equipped with actuators and can offer different types of stimuli on the foot through vibrations. It can communicate emotions by hapticons. *inTouch* [126] provides a physical link for expressing the movement or gestures of the remote person through haptic feedback. And *PillowTalk* [127] detects the interactions with pillows (touching, caressing, holding, throwing, hitting) and the movements of a pillow itself and communicates them to create ambient environment among an intimate social group. Design perspective of these communication medium is combining everyday artifacts with existing technologies and creating new technology. Table 2.2 summarizes some of the attempts in this theme:

Message	prototype	medium design	Stimulation
Kiss	Intimate mobiles [97]	direct telepresence on mobile	hand loop, heat, wet sponge, airjet
	kiss communicator [98]	Symbolic mapping	squeeze and blow
	Kissenger [128]	direct mapping on telepresence robot	vibration
	CheekTouch [99]	differnt vibration patterns	phone vibration and audio
	Hkiss [101]	haptic feedback from 3D avatar	vibration on belt
	XOXO [129]	direct mapping on telepresence robot	vibration
Hug	The Hug [102]	via telepresence robot	lights, vibration, heat,sounds.
	Hug over a distance [47]	through wearable vest	air-inflation
	Huggy pajama [103]	wearable hug jacket and hug trigger device	air pressure
	HaptiHug [4]	hug keyword,visualization and haptics	robotic hand pressure
	Second Life HugMe [104]	multimodal hug input	visuotactile on jacket and avatar
Co-Sleeping	Sensing Beds [119]	position tracking via mattress sensors	slow heating
	Aura [120]	sleep pattern sesning	music corresponding to pattern
Hand Touching	Tele-handshake [106]	shared virtual interface and hapticcs	feedback through phantom
	YourGlove [108]	paired robotic hands	hold and grip
	HotHands and HotMits [107]	personalized hand shape	thermal insulation
	Feelybean [109]	augment touch to skype	vibration
Biological Signals	Mobile Feelings [115]	heart beat/breath sharing	LED blink and pulses/ micro-ventilator
	united-pulse [116]	heartbeat share	ring vibration
Touch Gestures	Tug n' Talk [121]	belt-buckle with chains	chain moves
	Poke [122]	surface augmented on mobile	inflation
	The ComSlipper [124]	foot posture sensed emotion	vibration/warmth/light
	FootIO [125]	foot-stool	different vibrations
	InTouch [126]	paird rollers	vibration
	PillowTalk [127]	pillow detects hand gestures	ambient method

Table 2.2: A summary of prototypical systems, which mediate intimate behaviors.

2.5.1.6 Communicating near space interactions through humanoid telepresence robot

There has been several humanoid telepresence robots that could transmit non-verbal signals such as: *Geminoid HI-1* which transmits basic movements and voice of a remote person [130] and its miniature version *Elfoid phone* [131]. *Mebot* is another telepresence robot that displays the distant person's facial expressions and body gestures [43]. *Callo and Cally* robots are similar to Mebot and use cell phone display to show facial expressions [132], which can walk, dance and show facial expressions on receiving emoticons in text messages. Although these robots are not designed with the main aim of supporting intimate communication, their physicalness provides them with the potential to be improved and applied in intimate computing. The physicalness makes them a suitable platform for communicating nonverbal cues such as touches, proximity, physical space sharing and spatial dimension which are the unique characteristics of tangible media.

2.5.2 Technologies that provoke intimate reactions

One perspective on intimate computing is implicit affective communication. In this approach abstract interfaces can convey the sense of presence in absence in an ambient way. They do not transmit any intimate behavior directly, but they support emotional aspects of intimacy and provoke intimate reaction without explicit expression.

2.5.2.1 Implicit and poetic interactions

There have been several works that provoke intimacy through poetic interactions. The earliest of this type are *Feather, Scent, and Shaker* envisioned by Strong and Gaver [94]. They are paired devices that implicitly inform users when their remote partner thinks of them. In *Feather* interaction with a picture frame causes the feather to drift in the air. *Shaker* facilitates the exchange of tactile gestures through a simple remote force feedback mechanism. And *Scents* actuates ephemeral aroma at home when the traveling partner interacts with a photo frame. These prototypes convey romantic sensation through serendipitous and ephemeral attributes of interfaces. *Hintouch* [133] is a two-way ambient communication prototype with support of context information around a picture.

LumiTouch [134] is a pair of picture frames with the photo of remote users on each other's desk which are used as interfaces. When the sender squeezes the picture frame, her partner's picture frame display area illuminates corresponding to the input squeeze intensity. Different combinations of light intensities, colors, and pulses are decided by couples as a private language for their interaction.

Also *SmallConnection* [135] express faint information such as light, wind and touch using robotic technology. *Light* symbolizes the presence by synchronously turning on and off between two distant homes. *Winds* detects the sound in a remote place and spins in sync with it. And touch is transmitted by synchronized movement of paired buttons. *Virtual Intimate Objects (VIO)* [5] (see Figure 2.4) transmits one bit message at a time by clicking on a virtual circle on a task bar that brightens the remote persons' circle. Their design philosophy was to allow active interpretation via the constrained nature of the communication. In another study on VIO [136] users were evaluated using a logbook including open ended questions regarding the context of use. This study also revealed that this simple interaction has a rich interpretation which suggests the importance of usage context in remote communication technologies.

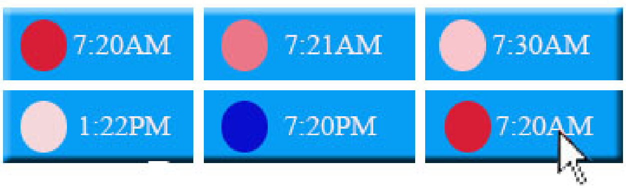

Figure 2.4: Virtual Intimate Objects [5].

2.5.2.2 Co-presence through hybrid sensory interaction

There has been several prototypes that express intimacy through hybrid sensory mode. Such as: *keep in touch* [6] (see Figure 2.5) that facilitates playful, visuotactile interaction with a fabric screen. Each persons' screen displays an out-of-focus video of his/her counterpart, that comes to focus after touching the fabric. *ComTouch* [118] augments touch to voice communication by sending vibrotactile feedback on the mobile phone during a conversation. *Shake2Talk* [137] is a mobile messaging system that facilitates sending audio-tactile messages by SMS. Messages are composed by four gestures of twist, stroke, tap, flick, which are mapped to different audio-tactile message and played to the sender as he/she makes the gesture. User evaluation showed it was mostly used by couples living apart.

Figure 2.5: Keep n touch. Touch-vision interface [6].

2.5.2.3 Shared experience

Matchus board and *Together aquarium* were based on the theme of experience sharing, in which the first one supports the experience sharing by facilitating synchronized drawing on a board using multi-user touch input and output devices and the latter through coordination of taking care of an online virtual aquarium [138]. *Lovers' Cup* [7] (see Figure 2.6) explores the idea of conveying the feelings of co-drinking as a communication channel for a couple in physically different places. The amount of liquid in each cup is shown in the partners' cup with LEDs and shaking the cup vibrates its remote pair.

Figure 2.6: Co-drinking experience through Lovers' Cup [7].

2.5.2.4 Simple awareness

BuddyClock [139] is a network-enabled alarm clock, which can share alarm status with alarm clocks within a social group. It is predicted that such natural status sharing may enhance social awareness, facilitate self-reflection and intimacy. Through long term deployment study between different social groups, it was found that the participants felt more connected. In the case of distant romantic couples after a few days their sleeping patterns were synchronized. *Cancan* supports awareness by using a button augmented on a watch which corresponds to a message: *cannot be available now* [138].

CoupleVIBE [140] is an awareness unobtrusive privacy-friendly, communication channel on a mobile phone. It shares the location information of remote partners by sending specialized touch cues when users move to each location. This medium allows them to be kept updated without being distracted from their daily activity.

Personal portraits rise or dim a remote photo frame based on the existence or absence of a key ring, which is an ambience representation of presence at home. *Light sculptures* uses light bulbs to show presence at home. And in *SoftAir Communication* pressure and movements are detected using sensors in the chair when it is touched and show the presence of the remote person by embedded lights and sounds on the touched surface [111].

2.5.2.5 Effort and mutual exchange

Another abstract approach which affords self-disclosure, communicates moods and shows effort and individualization is "sharing emotion through self composed melodies" [141]. This system allows users to compose and share melodies via mobile phones. It synchronously shares the emotional state of the sender. They found that self composed melodies have a strong impact on the receiver, which is similar to the effect of a crafted piece of art offered to a beloved person.

Lovers' box [142] is a digital artifact that aims to engage couples in reflection on their relationship. The role of refection which is through creation, exchange and sharing is examined using digital artifacts. In this work also, instead of prescribing the type of actuation and stimulation, individuals themselves are co-creators of the experience. The feeling communication interface was a box that could exchange self-created video messages between couples. The other factors that supported intimate interaction were being more customizable than text, private sharing, and giving & receiving. It also has ambiguity since it allows the users to interpret and analyze the message. *Audible gifts*, are inspired by the significance of *letters* since they have tangibility, thoughtfulness, and require effort which is a pair of microphone and speaker for sending five minute messages [138].

2.5.2.6 Fictitious co-habiting through sharing everyday artifacts and objects

Another group of prototypes use and adopt existing artifacts as a communication medium, instead of creating a completely new device. This theme is initiated by Dodge through a prototype named *The bed* [143]. By equipping pillows with heating pads and vibrating motors, presence and heartbeat of the remote person is symbolized. Colorful shadows on curtains correspond to the voice amplitude of a remote couple and sways are associated with the breaths. A bed is chosen as an interface since it is a shared physical space in F2F intimate interaction and is loaded with meaning.

Peek-a-drawer [144] facilitates virtually sharing drawers among remote family members. In this device when a user puts something in the drawer its photo is taken and appears in the remote drawer. *Habitat* [145] is a series of joined furniture for background awareness between distant couples. The initial prototype consists of two networked coffee tables, where each station consists of a computer, RFID tag reader and a video projector. Objects placed on the table are sensed by the RFID reader, and its corresponding representation is projected on the remote table. When objects are removed, their representation fades gradually.

SyncDecor [8] (see Figure 2.7) informs couples of each other's activity by synchronizing daily appliances. This system can remotely synchronize lamps, brightness, trash door open, TV channel, and smell between remote couples. *Magic Sock Drawer* [146] enables the creation of digital hand-drawn or typed messages and then automatically produces the physical printed version in the remote users' drawer. The system design supports four intimate computing design concepts including: exchange between dyads, personalization, tangibility and location sharing.

Digital Selves proposed by Grivas [147] approach fictitious merging of the homes of remote couples. This system recognizes the positions of electronic objects inside the two separate homes of a couple living apart. The advantage over simple ambient communication is adding spatiality and creating the sense of place.

Figure 2.7: Fictitious cohabiting through syncdecor [8].

2.5.3 Relative distribution of intimate communication prototypes

The above described technologies can be mapped to a two dimensional design space that shows their relative distribution in terms of abstractness compared to holism in one dimension, and poetic design compared to literal design in another dimension.

The abstract prototype design, points to a design perspective that recreates and communicates minimal features related to an intimate interaction. One example of abstract design is *VIO* [5] which, allows users to send to their partner a very simple, one-bit message for communicating intimacy. The holistic design approach, which opposes the abstract design perspective, refers to recreating the partner's presence with maximum embodiment. As an example of a holistic telepresence interface, *Geminoid HI-1* [148] could be named. Geminoid HI-1 is a human-like telecommunication medium, although its is not designed for the purpose of intimate telepresence, it can be considered as a benchmark to clarify the meaning of holistic presence.

The other dimension of the design space refers to poetic and literal design. As explained in section (2.5.1), literal is an exact recreation of intimate behaviors and poetic is mapping the behavior to another form which is more subtle and indirect.

Figure 2.8 shows the relative distribution of some of these technologies that are described in the previous sections. They are classified based on the degree of holism and realness versus abstract and poetic presence that they convey.

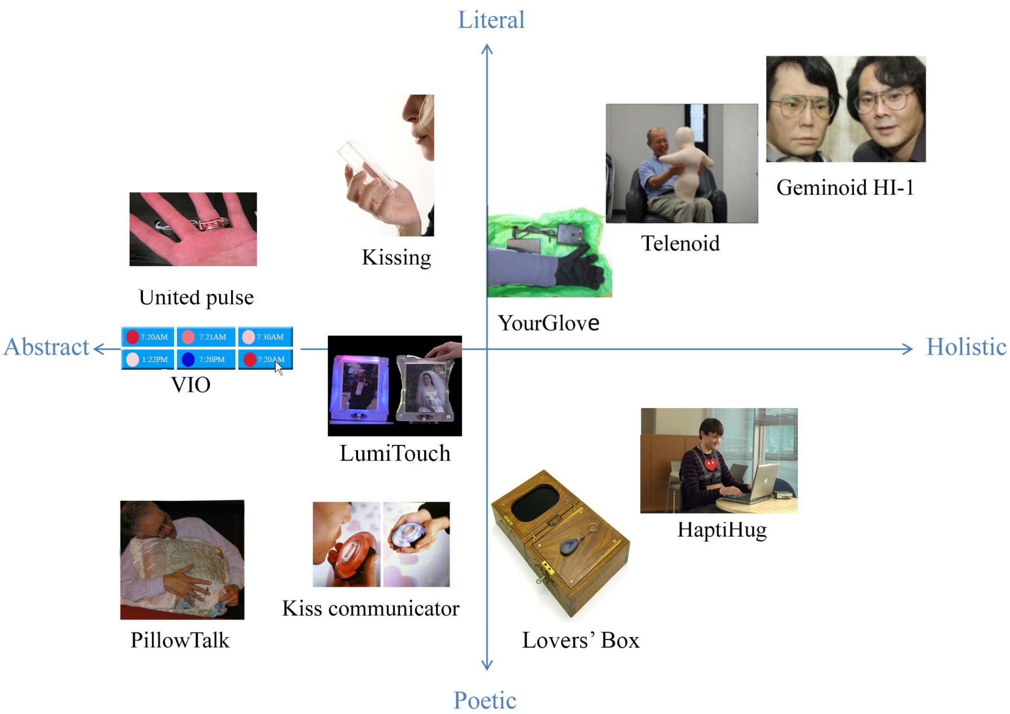

Figure 2.8: Relative distribution of some of the telepresence technologies.

2.6 Discussions on the Knowledge Gaps of the State of the Art

In this literature review we have attempted to explore a broad outline of the field of intimate computing, including relevant conceptual descriptions, human factor elicitation, technical mechanism, and current design trends, fueled by psychological attributes, as well as trends in affective computing, social technologies, and telepresence. This field has gained a lot of attention over recent years. The prototypical systems and design perspectives reviewed in the present survey have set the stage for future studies on intimate computing by inspiring researchers, designers, and developers by providing a description of the state of the art.

However, it seems that in design investigation and point solutions, there is still ambiguity in approaches that would best support LDR. Deeper conceptual understanding on the nature of intimacy and practical experiments on the effects of mediated intimacy is needed. Due to the private and delicate nature of intimacy, conventional human subject exploration techniques such as ethnography are not efficient enough. There have been several attempts in the use of technology probes [60] but since the current attempts are still rudimentary, more encouraging and well designed technology probes are still needed. This thesis has explored more on the usage of technology probes for intimate communication in chapter 4.

To date very few objective evaluation techniques of developed systems are available beyond the simple descriptions by users or quantitative analysis with few participants. Studying the long term effect of intimate interaction through developed mediums and benchmarking among different suggested designs is rarely experienced. We recommend more detailed studies on the user acceptance of such a novel trend of communication, and also studies of potential cultural, gender and age differences in the degrees of acceptance and ethical issues. What the relatively new area of intimate computing would benefit most from at this early stage is more studies that put the assumed design decisions, described in the reviewed literature to the test and practice in the real world application. Field study performed in 6.2.3 explores one of these technologies in its real usage context.

One important issue is that these systems need to be tested on people who are already in the LDR circumstances. These devices have not been designed for co-located couples. The aim of these technologies is not to replace the available natural modalities, but the research should focus on providing solutions for people who are far away for some reasons. Therefore more studies with samples of people in LDR is suggested. This is also explored in 6.2.3

So far, the common theme of intimate computing technologies is pairing abstract devices that are connected through the internet and enable simple interactions. However, a holistic telepresence medium that provokes or expresses intimacy is not yet developed. Chapter 4 explores the design specification of the holistic telepresence agents using technology probe.

Another research gap is the lack of an intelligent agents that could also act independently instead of only transmitting the nonverbal cues. Also improvement in usability (exp., non-disruptiveness, embedding in current communication medium instead of separate devices, and portability) is suggested. An exploration on this issue can be seen in chapter 5 of this thesis.

Chapter 3

Overall Methodology

3.1 Introduction

The main methodological approach of this study is anthropologically inspired robotic, which is performed based on iterative multilevel modeling. At each level different dimensions of intimacy are studied. Physical and cognitive intimacy are designed and developed using an iterative prototyping methodology. The other type of modelings in this dissertation is modeling the AI for the control system which is associated with emotional intimacy. The first two levels of modeling are physical models (Robots), whereas the AI model is a stochastic model designed for the agent's behavior control.

3.1.1 Anthropologically-inspired robotic approach

In this study the anthropologically-inspired-based robotic approach is proposed for recreating the presence of an intimate partner through artificial agents. Anthropology is the study of humankind, which draws and builds upon knowledge from the social and biological sciences as well as the humanities and physical sciences [149]. Therefore, anthropologically inspired robotic could be classified as a sub-category of biologically inspired robotics. This field of biologically inspired technology, has evolved from creating static copies of human and animals in the form of statues to the emergence of robots that perform realistic behavior [150]. Biologically-inspired robotics as the name implies is about making robots that are inspired by the biological systems. Bio-mimicry and bio-inspired design sometimes gets mixed up. Bio-mimicry is copying the nature while bio-inspired design is learning from nature and making a mechanism that is simpler and more effective than the system observed in nature [151]. The proposed mechanism consists of three levels of sensing, control and user interface as illustrated in Figure 3.1.

Among the different experiences of humanity, the present study has focused on intimate interactions. Therefore, inspired by the concept and attributes of intimacy, aspects of human face-to-face interactions, which are related to intimate interactions between dyads, are recreated or transmitted through the agents in another location.

As discussed in 2.2, intimacy is a multi-dimensional concept. We have focused on emotional, physical and cognitive aspects in this study. **However, it should be noted that there is no strict boundary between different dimensions of the intimacy. A behavior at the same time could trigger more than one**

dimension at the same time.

- **Cognitive Intimacy:** Some aspects of cognitive intimacy are recreated based on the concept of enclothed cognition and recreation of the physicalness and appearance of the remote person. This subsystem studies the physical properties of the telepresence robot with the focus on the effect of personalization.

- **Physical intimacy:** Physical intimacy is addressed by detection and recreation of kisses in the remote location. This section suggests a design framework for teleporting kisses. However, the system architecture and the engineering of the system could be applied to other touch-based nonverbal behaviors too.

- **Emotional Intimacy:** Being emotionally intimate or being within emotional, personal space, could be described as knowing what the partner feels deep inside. In this study emotional intimacy is recreated by focusing on comprehending and reacting to the mood state of the remote partner. An artificial intelligence model for inferring the mood state of each user dynamically and recreating it in another location through an artificial agent is modeled. Providing appropriate feedback to the detected mood state is also another methodology used in this study. In an integrated system this model could act as the brain or the controller of the telepresence robot too.

3.2 Iterative multi-level modeling

Iterative multi-level modeling [152] is adapted to develop and analyze the artificial agents for intimate telepresence. In this method a system is designed as it evolves, therefore evaluation could be an integral part of the design process. The reason for choosing this method is that it helps to discover design and specify functionality properties of the system. It helps to minimize the issues and failures after industrialization and application in its usage environment.

Multilevel iterative modeling facilitates design "from the outside inwards". The fundamental concept in iterative multi-level modeling is the co-existence of several representations of the systems with different abstraction levels. The multilevel method accounts for models that are nested in higher ordered models. In which, nesting means each unit belongs to a category which is a unit of another category higher in the hierarchy.

In the context of this research, body languages, intelligent controller model and haptic interactions are parts of the holistic system of the telepresence robot. In this study "outside inward" modeling of intimate telepresence is initiated by modeling of the physical properties of the intimate partner's synthetic agent. Afterward, the focus has moved to the recreation of nonverbal behaviors related to affective communication and finally to the intelligence and behavior control of the agent.

In this respect, initially a humanoid robot, which is a representative of the intimate partner, is designed via the minimum viable prototype (MVP) in chapter 4. Then in chapter 5, an Artificial Intelligence (AI) model is proposed and simulated to mediate cognitive intimacy for the synthetic agent. The AI model also could act as the behavior controller for the synthetic agent and activates the appropriate nonverbal behaviors based on the context. Afterwards, physical intimacy is replicated through the iterative design and development of telepresence robots for kiss communication in chapter 5.

The research is initiated by the research question of *How to facilitate intimate communication across distance by means of novel interactive telepresence technologies.* This in turn is narrowed down to the study of mediated holistic physical presence, mediated kisses, and intelligent affective telepresence. Each of the models itself is developed through synthesis, analysis, and iterative modeling. And each model is designed based on anthropologically-inspired robotic to represent the intimate partner. The following sections describe the methodological considerations in different stages of the study.

3.3 Methodological approach in controlling the agent's behavior

Overall, three types of control mechanisms are implemented to control the agent's behaviors in relation to each of the intimacy dimensions.

- Cognitive intimacy: Recognizing the body languages generated by remote users, using video based gesture recognition technologies, and recreating them via the personalized physical agent on the other side.
- Physical intimacy: Detection of the amount of force on the agent's lips and recreating the corresponding force on its paired agent on the other side to emulate remote kissing.
- Emotional intimacy: Estimation of the mood states of the users using Smartphone data, teleporting and reacting to them.

Also, behavior networks are adopted to decide which goal should be triggered to control the robot. The reason that this model AI could also act as the controller of the whole system, since it can decide which nonverbal behavior should be performed. Therefore, it could, for instance, trigger kissing, waving, or appropriate facial and body expressions, considering the inferred contextual data.

In the following chapters, each of them will be described in more detail.

3.4 Methodological approaches in the design of the user interfaces

The design methodology applied in this research is iterative prototyping (Figure 3.2). Prototyping is an activity with the purpose of creating a manifestation

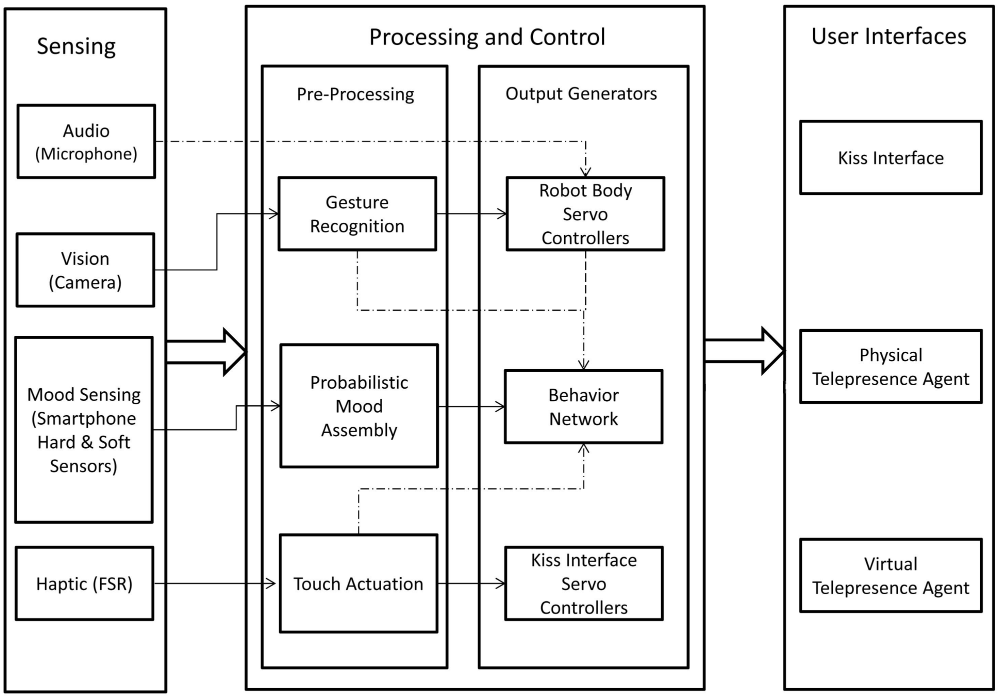

Figure 3.1: Overall system architecture, showing sensing, control and use interface in three different dimensions of intimacy

that, in its simplest form, filters the qualities in which designers are interested, without distorting the understanding of the whole [153]. Iterative prototyping is a prototyping methodology based on a cyclic process of design, test, refine, and evaluate. Considering the results of testing the latest iteration of a design, modifications and refinements are made. The ultimate goal of this process is improvement in the quality and functionality of the prototype.

Iterative prototyping starts with low fidelity prototypes such as sketches. Low fidelity prototypes allow the capture of rough ideas quickly and cost effectively with emphasize on the big pictures and support design thinking. They

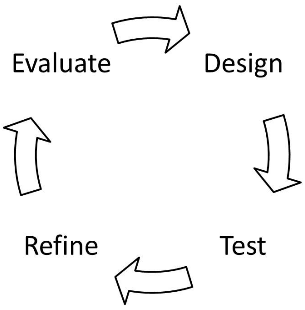

Figure 3.2: Iterative design process

facilitate brainstorming, and also their simplicity allows elicitation of users' suggestions without limiting their creativity [154].

After several iterations, the early stage prototypes evolve gradually to medium fidelity prototypes. Medium fidelity prototypes are good for futuristic ideas. One example of this level of prototyping is prototyping with a computer, such as a simulated or animated version of some, but not all of the features of the intended system. In medium fidelity prototypes, approaches such as wizard of Oz (WOZ) or scenario-based evaluations are used. In WOZ evaluation method, a human simulates the system intelligence and interacts with the user. Medium fidelity prototypes can be evaluated within lab environments and provide a design framework for futuristic ideas [155]. More evolved prototypes could be evaluated by case study Methods and within their real usage environment.

The following three chapters will describe each level of the modeling in details.

Chapter 4

Intimate Telepresence through Physical Agents

4.1 First level of modeling: Physical agents modeling for affective telepresence

This chapter describes the first level of multilevel modeling. As explained in the methodology chapter multilevel iterative modeling facilitates design "from outside to inward". Assuming that the ideal goal is creating dual presence of a remote person, the development procedure is initiated by the development of physical surrogates of the interacting partners as the basic platform.

While, methods such as video conferencing are commonly used in telecommunications, in this study the focus is on physical interfaces. The reason for focusing on physical avatars is mainly the potential of telepresence robots in having physical effects, such as touches and moving objects in remote locations. Therefore, they could be a suitable platform for intimate communication. The platform is then evolved stage by stage, and in the form of independent models towards the goal of supporting the sensation of direct face-to-face communication. The following sections explain the concepts behind the design decisions and development procedure.

4.2 Related theoretical concepts and design justifications

Compelling evidence reveals that emotions are one of the necessary parameters for improving the sense of closeness and more presence might end up with more arousal and affect [156]. Butler et al. [157] have justified that emotional suppression leads to decreased chances of forming new relationships. Moreover, the omission of nonverbal signals might obscure the sender's intentions, which may lead to misunderstandings and extreme reactions [158]. Since partners' emotional convergence enriches the relationship quality [159], the negative effects of separation from the romantic partner should be ameliorated by different methods such as sharing affective experiences [160]. Considering the importance of emotions in affective communication, it is necessary to look at potential ways of enhancing and expanding the range of signals through which we communicate our emotions to a remotely located person [90].

In current telecommunication techniques feeling expression means are limited to emoticons, stickers and words in chats and text messaging audio in voice calls, or audio and facial expressions in video call systems. Although a wealth of emotional content can be perceived from these channels, their delivery on the cold, sterile screens of smart phones and laptops make them very distinct from live face-to-face communication. One reason for this perceived difference might be the lack of a physical body in the conventional communication mediums. Using bodily signals, such as facial expressions and gestures, is essential in communications [161]. A physical body is missing from the experiences of many virtual interactions such as those rendered using a head mounted display (HMD), online virtual worlds and second life, which will result in an impoverished sense of presence [162]. Although some of the body languages are offered in virtual experiences, still many features of co-presence are perceived when users share physical proximity. Proximity is essential in high fidelity emotional interactions, since social entities often do not only rely on verbal signals, but also on nonverbal signals such as body languages, posture, touches, facial expression and eye gaze. The lack of these important nonverbal cues incorporates the significance of embodied telepresence on communication [23]. Therefore, it might be worthwhile to look at physical, emotional cues that can be tracked and transmitted by telepresence robots and may serve as an intimate signals.

Among the nonverbal cues that could possibly contribute towards enhancing the emotional dimension of physical telepresence, we have focused on appearance. Appearance is studied as a parameter that could influence on the quality of interaction. We have explored how the robot's appearance and personalization influences the user's experience in terms of affectivity and co-presence with the focus on designing for intimate communication. The reason for choosing the mentioned nonverbal cue is the relation between cognition and attire, which is defined under the concept of enclothed cognition. In virtual forms of communication, users commonly project themselves via buddy icons or 3D avatars in which their appearances are often customizable. The need and behaviorial effects of virtual avatar modification in 3D virtual environments is widely studied and supported by previous researchers [163, 164, 165]. However, to the best of our knowledge, study on physical avatar personalization is still in its infancy.

4.2.1 Importance of nonverbal behaviors in intimate presence

"Actions speak louder than words", the saying goes and holds true in human interactions [166, 167]. In every moment, whether we are verbally silent or not, we are communicating messages to one another. People react to nonverbal signal, as much (if not more) as explicit verbal messages. While we are interacting face-to-face, we constantly send signals about our attitude, feeling, and personality by both verbal and nonverbal signals. These two signals act together and are inseparable parts of the whole communication process [168]. It is argued that the conversation depends on all communication channels through which communication signals are exchanged by individuals all along face-to-face interactions [169]. Misunderstandings usually happen when people cannot perceive or communicate subtle parts of their interaction.

Language is closely connected to and supported by non-verbal cues, which complement the definition of utterances, while sending feedback, and also play a central role in human social behavior [170]. Although facial expressions are the most well-known means of non-verbal signaling and have gotten the most attention by researchers, body languages are also important mediums for emotional expressions [171]. A supportive evidence points to classical animation which claims that the expressions are needed to be captured all over the body including the face. Even theater supports this theory, by asking the actors to become, in Artaud's words, "athletes of the emotions" and a significant portion of an actor's training targets the nonverbal expression of emotions [172]. Nonverbal signals are specifically important in intimate interaction, which is "a joint function of eye-contact, physical proximity, intimacy of a topic, smiling, etc. [173]."

In face-to-face interactions, couples in romantic relationships in the real world might spend emotionally rich times by nonverbal communication without having any conversation. Nonverbal signals which carry emotional loads not only consist of facial expression, paralinguistic, eye contact and postures which can be perceived through auditory and visual channels but also include proximity, tactile interactions, body orientations, and object languages. In the context of this research, proximity signifies the distance between communicating parties which implies intimacy and comfort level [174]. Tactile interactions are also closely related to intimate aspects of communication. In close relationships, people touch, embrace, hold hands, shake hands, and perform tactile communications, although it varies in different cultures. Body orientation in the spatial context also conveys emotional messages which are compromised in virtual environments. Object languages refer to the display of material things such as, attire, accessories, hairstyles and so on, which in the context of interpersonal romantic relationship encompasses the exchange of symbolic objects such as wedding rings as a sign of commitment. Emotional dimension of social presence, is perceived easily by observing nonverbal signals.

Although the temporal and spatial distance between communication in computer-mediated communication acts as a barrier in receiving non-verbal signals [175], yet certain computer technologies might compensate for these drawbacks. Artificial humans represented through "Embodied Conversational Agents" and anthropoid robots can facilitate human social interactions due to their unique human capacities of interpersonal interaction and social information processing. The "new Artificial Intelligence" has considered the affective communication aspects with emphasis on understanding as well as the production of nonverbal behavior [176].

4.2.2 Embodied cognition and embodiment

According to Wilson and Foglia "Cognition is embodied when it is deeply dependent upon features of the physical body of an agent, that is, when aspects of the agent's body beyond the brain play a significant causal or physically constitutive role in cognitive processing" [177]. Unlike traditional cognitive science which describes cognition as a process of symbol manipulation, embodied cognition emphasizes on the importance of the body of an organism on our perception [178].

There are different perspectives on embodied cognition in which the most powerful one is that "off-line cognition" is body-based. In this view point, off-line cognition refers to those behaviors in which sensory and motor resources are used for mental functions whose referents are distant in time and space [179].

Dourish [180] suggested the paradigm of embodied interaction that combines tangible and social computing, as "the social and tangible both taken to their extreme can lead to the intimate" [97]. Embodiment is an important concept whose importance is widely acknowledged, especially in the area of interpersonal interactions. For instance, Lombard and Jones have suggested considering issues from diverse perspectives such as, embodied or grounded cognition in philosophy as a potential research direction in the area of telepresence and sexuality [181].

Embodiment is defined in many different ways, and is difficult to explain the concept of embodiment in one definition. However, it is mostly referred to as possessing a physical body for grounding sensorimotor behaviors and cognitive aspects of interaction. Pfeifer and Scheier defined embodiment as follows: "Embodiment: A term used to refer to the fact that intelligence cannot merely exist in the form of an abstract algorithm but requires a physical instantiation, a body. In artificial systems, the term refers to the fact that a particular agent is realized as a physical robot or as a simulated agent" [182].

Although visual perceivable graphical representations are another type of embodiment [176], in most literatures, embodiment is referred as physical and tangible entities that can be presented in the real-world. It seems that higher level of embodiment which includes spatial co-presence and tangibility is more convincing in richness of mediated environment.

Despite the fact that virtual representation is a conventional form of telecommunication, a host of research has documented the advantage of physically embodied agents over computer-graphics and "in the screen" representations. Several examples are as follows:

- Wainer et al. [183] investigated the effect of physical embodiment on the perception of social interaction and concluded that physically embodied interfaces were favored over virtual agents and remote teleconference systems. Their study upholds the importance of material embodiment in social interactions. They realized that presence of physical robots were more joyful, believable and watchable than either virtual agents or even physical agents separated via a video conferencing setup.

- Shinozawa et al. [42] stated "the leap from on-screen to off-screen would represent a substantial difference in the social responses that an agent could elicit". This kind of preference of embodied agents over the virtual ones, might be attributable to the tangibility which plays an important role in natural interpersonal interactions [183].

- Ishii [184] has signified seeing virtual objects through graphical user interfaces (GUIs) to looking into a pool of water, which are interacted with indirectly, and believed that virtual object does not benefit from heightened ability to sense and manipulate the physical world and hand-eye coordination capacity.

- Kwan Min Lee et al. [183] have compared physically embodied social agents to disembodied ones. They found that the physical embodiment of a social agent intensifies its social presence which has a direct relationship with people's positive social responses to the agent. They also emphasized that a bodily presence could significantly improve the affectivity of social interactions between human and social agents and stated that "physical embodiment is not a luxurious option but an essential dimension of social agents.

- Kidd and Breazeal [185], conducted an experiment to compare computer graphic agent with physical agents and found that physical agents were perceived as a better communication medium. It was also found that the material embodiment allowed robots to be perceived as a real entity, while the virtual agents were perceived as a fictional thing.

- Shinozawa et al. [186] also found significant difference on perception of affectivity in comparison between the effect of a robot and on screen agents in persuasion, and argued that a 3D body is more appropriate than 2D representation when the context of interaction is a 3D space. It can be one of the reasons for finding a salient difference between conventional video communication systems such as Skype which lacks 3D features to face-to-face interactions.

4.2.3 Enclothed cognition

One of the theories that supports our design decision is "enclothed cognition", coined by Adam et al. [187]. Enclothed cognition describes the systematic influence of attire on the psychological processes. The study suggests that clothes have impacts on the wearers by co-occurrence of two independent parameters which are their symbolic meaning and the physical experience of wearing them. Victoria stated that: "We think not just with our brains, but with our bodies" , our mind processes based on physical experiences that contradict associated abstract concepts. Now it appears that those experiences include attire as well [188].

Similarly, attire as a signal of nonverbal behavior has the same power over others. "What a strange power there is in clothing" noted Nobel-Prize winning author Isaac Bashevis Singer, asserting the power of clothes on perception [189]. There are many supporting evidences that verifies the effect of dress on the perception of people. For example, Baker and Wanger argued that customer service personnels who dressed appropriately could elicit purchase intentions [190]. Chung et al. found that the doctor's clothing plays a significant role in establishing confidence, trustworthiness and perception of empathy in the patient-doctor relationship [191]. Best-selling books like *Bodily communication* highlighted the power that attire can have over others by creating affirmative impressions [192]. Therefore, attire seems to be an important communication channel which affects the perception. This sparks the idea of embodying the communication interface with the experience-reminding attire.

4.3 Concept identification

Generally, telepresence refers to a set of technologies which allow a person to feel as if they were present, to give the appearance of being present, or to have an effect, via telerobotics, at a place other than their true location. In short, telepresence means "feeling like you are somewhere else", which pertains to a set of technologies that conveys the perception of being present or have an effect on a remote environment [193].

Telerobotics is a variant of telepresence. This communication interface incorporates information and communication technologies (ICT) onto robotic platforms to enable presence or sometimes actuation at distant locations. Telepresence robots are mobile machines that act as the people's stand-in at a remote location [43]. Such systems enable the remote operators of the system to embody themselves within the form of a robot in a remote environment. It is done by embodying users in a way that facilitates them with the acceptable likeness in the remote site, so that they can be immersed in the context and be felt by their interaction parties as being similarly present [194]. We believe that telepresence robots are worth studying for intimate telecommunication since people can share physical space.

4.3.1 Related works on telepresence robots for social telecommunication

There are few works that have used humanoid telepresence robots as a medium to recreate the physical presence at remote distances. For example, Greenberg and Kuzuoka [195] proposed *digital but physical surrogates* as tangible representations of distant intimate team members to be located within an office and collect and send awareness information about the people they represent and react to their explicit and implicit physical actions.

Mebot is another telepresence robot with a small screen atop a three-axis neck that displays the distant person's facial expressions, as well as wheels and pair of moving arms which are designed to convey body gestures to the other party as the bot moves around [43]. *Callo and Cally* robots are similar to *MeBot* and use cellphone display to show facial expressions [132]. They can walk, dance and show facial expressions on receiving emoticons in text messages. *Callo* is programmed to perform predefined behaviors based on the emotional content of the text message. For example, when it detects a frowning gesture, it slumps its extended arms and shows cry face on the display.

Silicon Valley start-up *Anybots*, introduced one of the first commercial offerings in the field of telepresence robots as an exotic looking robot named *QB* [196]. Ishiguro introduced *Telenoid* with a generic face, and a body shape between human and mermaid. It is 80 cm in length and can mimic the basic movements and the voice of the remote person [130]. The Elfoid phone is a miniature version of the same robot, which is 20 cm with a genderless and ageless appearance [197].

Among all the above examples *Telenoid* and *Elfoid* are the closest to our study, although their generic appearance compromises enclothed cognition. Overall all the mentioned robots have tried to rebuild the physical characters of the remote person to some extent, however, none of them have considered personalization with the aim of facilitating intimate and emotional communication. In this study, the

4.3.2 Design decisions on physical agents for affective telepresence

Based on the survey, it was found that the effect of nonverbal cue of personalization is not studied in telepresence robots and intimate computing technologies. In this study we try to address these issues by proposing a medium to reproduce the physical features and body languages of a remote person through the development of a personalized robot. We use the term personalization to refer to the ability to customize the appearance of the robot, by emulating the specific cues of a remote person. Blom and Monk [198] described personalization as "a process that increases personal relevance to a system by accentuating distinctiveness of its nature". Chatley et al. [199] defined personalization by "altering the colors and visible appearance to tailor the robot to what the user saw as the ideal embodiment."

We term our proposed medium as *Mini-Surrogate*, since it is supposed to be a miniature representation of the remote person. It consists of two robots, coupled together, where each robot is the look-alike miniature version of the remote person, and will imitate the body movements of the distant individual. Each robot leverages on the body languages through the camera mounted on the user's computer and sends it to the gesture reproduction module of its coupled robot. The other robot uses the received data, processes and reproduces the gestures performed by the initial user. It facilitates the communication of physical features such as spatial mobility and body languages (see Figure 4.1). The significance of activity logging and reflection is supported by many previous studies such as [200, 201, 202]. This kind of reflection is especially beneficial for scenarios where face-to-face communication is impossible, as it enables the partners to be virtually present at any remote location.

Theoretical considerations discussed in the previous sections are applied in our decision in the sense that the proposed communication medium is tangible and embodied. Enclothed cognition is applied to personalize the appearance of

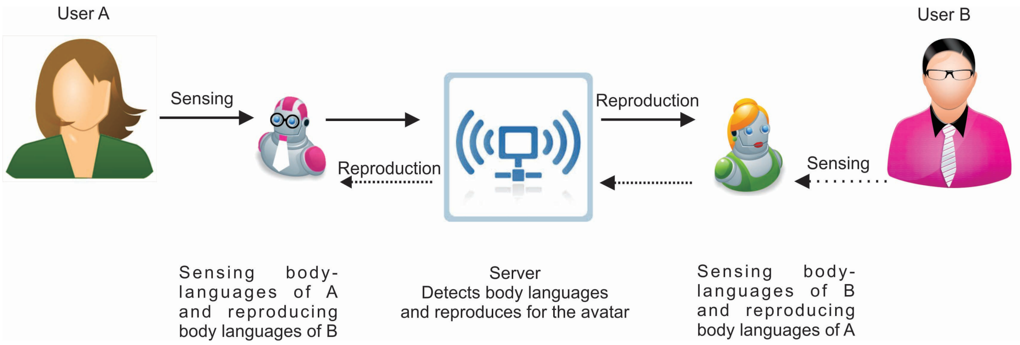

Figure 4.1: Mini-Surrogates System Overview

each robot through clothes and accessories to remind each user of their remote partner. Nonverbal behaviors, which are needed to be produced by the proposed medium, are decided considering the minimal viability. To begin with, the design of the prototype is capable of reproducing a minimal set of nonverbal cues such as moving forward and backwards, turning, nodding, and waving. Based on two projects by Kaye et al. [203, 204], technologies designed to mediate personal relationships are often simplified with a small set of possible acts of communication. They present a type of contact that is sufficiently vague to be interpreted as a show of tenderness, while preventing the communication of specifics. This kind of minimal communication allows and requires users to interpret each signal based on their own and their partner's context.

The following sections describe the step-by-step design procedure, technical features, and evaluation.

4.4 Creating Mini-Surrogate

In this section the step-by-step design procedure of mini-surrogates with the aim of designing a telepresence system for couples in long distance relationships (LDRs) is described. Iterative and participatory design procedures are described in detail.

4.4.1 Iterative design process of Mini-Surrogates

Mini-Surrogate was developed in three iterations, that progressed from generating the idea by sketching, towards defining the form factor of the device, then towards the feasibility of the implementation and personalizability of the prototype. Our design approach was inspired by iterative prototyping methods.

4.4.1.1 First iteration of Mini-Surrogates:

For the first iteration, in a focused group session, design ideas were generated and then detailed by drawing idea sketches (see Figure 4.2). Participants were asked to generate design ideas on the appearance of physical avatars for telepresence. At this stage we looked into various shapes of the interface. The main issue was that it was preferred to have an interface with a natural form factor similar to human and small enough to make it possible to be carried along.

4.4.1.2 Second iteration of Mini-Surrogates:

Armed with the feedback from sketching step, we decided to develop a lifelike and exact copy version of two of our team members as a minimal physical prototype of the second iteration,. They were 10 cm in height and have a slim body which makes it easy to hold like a mobile phone. These prototypes were made without internal circuitry for the purpose of facilitating brainstorming and investigating the required modifications and technical implementations (see Figure 4.3).

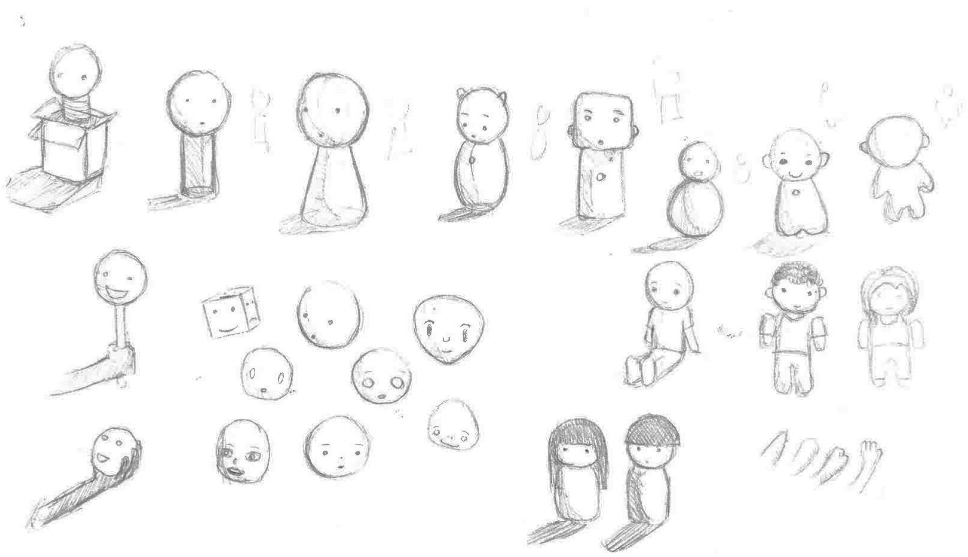

Figure 4.2: Iteration one for Mini-Surrogates: design ideas detailed by drawing sketches

Figure 4.3: Iteration two for Mini-Surrogates: Proposed shape of the robots.

Using the concept prototype shown in 4.3, concept assessment and feasibility study was performed in a focus group with 9 heterosexual couples with previous LDR experience. The participants were chosen from the student and staff body of the National University of Singapore.

The study was initiated by briefing the users about the overall concept and its vision. It was followed by encouraging the participants to puppet with the prototype while at the same time we were observing the participants behavior and inferring their verbal feedbacks during the practice session. Our goal was to know whether the users could envision the merits of the communication through this sort of physical representations over the virtual (non-physical) forms. We also wanted to know how the design should be modified to afford its goals.

In general, users were positive towards the idea, specially the likeness of the robot appearance to its users received positive feedbacks. One important issue that arose was related to the possibility of interface personalization. The fixed face, body, and clothes of the concept prototype distracted from the goal of personalizability. It was preferred to slightly modify the interface to make it possible to personalize the appearance of the robots for each user.

4.4.1.3 Third iteration of Mini-Surrogates

Considering the feedbacks from the previous stage several design modifications were made. Also, to make it practically possible to develop the real robotic interface with internal circuits and with a low cost the size was slightly increased. The new prototype size was 35 cm in height, which in turn made it embraceable. This version is customizable to look like a specific person by changing the hairstyle, attire, and accessories. This is similar to the way that virtual avatars are customized, but it is done in the physical world. This flexibility facilitates the usage scenario by giving the choice of accessories for the robot to users. However, to avoid the biases in the formation of the relationship we personalized the robots for users, referring to their photos, prior to the experiment [205]. Also, in this version in order to minimize the uncanny feeling which might be perceived by realistic design we targeted for a toy-like design instead of an exact copy of the users as was done in the body previous version.

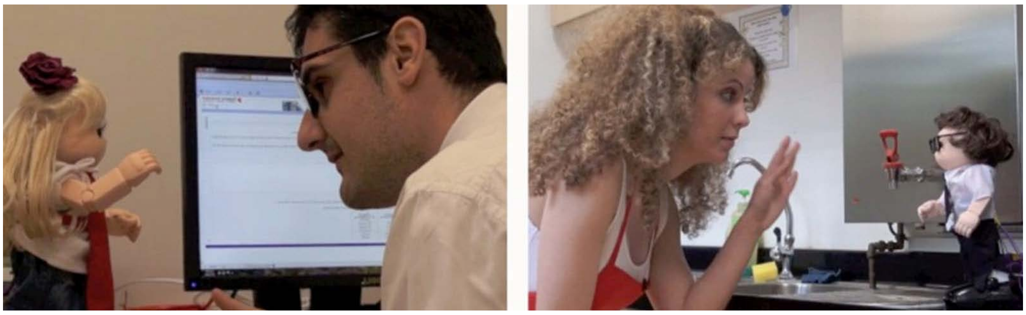

Figure 4.4: Iteration three of Mini-Surrogates: Personalizeable robotic version

4.4.1.4 Towards anthropomorphism of Mini-Surrogates

In the design of the robot, the body movements and size have common advantages in co-located human-robot interaction. It helps gesture reproduction, and its minimal gesture reproduction, aesthetics and unrealistic appearance might reduce the risk of uncanniness [96], although more empirical evaluations are still needed to prove this issue [206]. We decided to make the head of the robot larger than normal size similar to cartoon characters. Assuming that a more engaging and playful appearance will make it more pleasant and engaging, which could subsequently foster the sense of intimacy with the robot. The other reason for the decision on the head size was to build a platform which will allow integration of facial features and expressions in the future. Also referring to the studies by [207, 208], robot wide head, detailed eyes with eyelash, nose, chin and facial curves and skin are designed with the aim of balancing humanness, robot-ness, and product-ness.

To show the articulated degree of freedom for MVP a basic 3D model of the mini-surrogates are shown in figure 4.5 which includes:

- Move backward and forward and turn
- Look side to side and up and down
- Raise and lower arms
- Curl and extend forearms

Prior to the implementation phase, we considered four major specifications for the robots:

- The robots have two modes of operation including, semi-autonomous and teleoperation mode. In semi-autonomous mode some of the robot movements are contorted by remote user's gestures. In teleoperation mode the user controls the robot using a graphic user interface (GUI). In both modes

Figure 4.5: Articulated degree of freedom of Mini-Surrogates

a user should be able to control the movements of the robot remotely through a wireless connection.

- The robot should have two variants (form factors) of a male and a female.
- The head should be easily replaceable as each robot is differentiated by the design of the head, clothes, hair, and accessories.
- Electronic components can be integrated into the base of the robot. No internal components should be visible to the user.

4.4.2 Teleoperation control mode of Mini-Surrogates

The teleoperator interface, enables the operator to control the robot body parts remotely by dragging the sliders. The operator can see the robot in remote location using a camera. The sliders correspond to pre-defined motions such as head node, waving, coming forwards and backwards, turning, etc. These motions will be executed in priority to the automatically detected movements. Figure 4.6

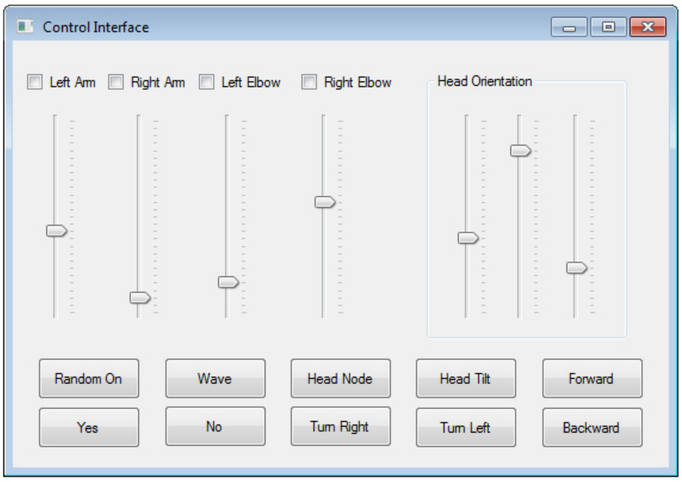

Figure 4.6: A screenshot of the teleoperator control GUI, The operator can control different body parts by dragging the sliders

4.4.3 Implementation of semiautonomous control mode of Mini-Surrogates

To achieve the required embodiment, initially we prepared two small humanoid robots with the ability to perform basic gestures. We customized the robot's look with cloth, hair, face, color, and accessories, making it resemble two members in our laboratory. At the end of the masking process, personalization of the robots was achieved through the following points:

- Each robot was made to resemble its owner in body features including, clothing, and hairstyle.
- The robots were made to be controlled remotely by the owner and each robot is equipped with a camera, so that the owner can view the surroundings of his or her own Mini-Surrogate.
- The robots were able to mimic minimum human gestures such as com-

ing backward and forward, turning, waving, moving head backward and forward, nodding by pan and tilt to express agree, disagree, timidness, excitement, shyness, etc.

Mini-Surrogate consists of two robots that communicate remotely. They recognize and reproduce some of the body languages of the person they represent at the remote location. An overall framework of the system from gesture detection until reproduction through robot is as below:

- User performs a body language.
- Software identifies the performed body languages sensed by camera and defines the correspondent movement for the remote robot.
- Data is transferred to Arduino using Xbee.
- Motors are enabled accordingly.
- Similar body language is performed by the robot.

The following sections describe the technical details on body language recognitions.

4.4.3.1 Head gesture recognition and replication for Mini-Surrogates

In order to facilitate the robot with the ability to imitate the body languages related to the head automatically, we implemented a head pose and orientation control interface. To achieve that we used a software library named FaceAPI developed by Seeing Machines [1] as the head tracking engine 4.7. Face API can identify the position and orientation of the detected face in radiant, which makes it suitable for the purpose of this study. It enables us to track the face within one degree accuracy and the head motion in ±80 radiants can be successfully detected. It is also robust to partial occlusions, illumination, variation of skin color and glasses. This library uses the video stream from the webcam as input and detects the human face, as well as lips and eyebrows. After detecting the face, the 3D position of the face in the scene and its orientation are estimated. After getting a research licence from this library, we implemented an application that could send these values to our control interface to control the robot head movements 4.8. The Z depth of the face is mapped to the head extend, the y rotation to the head pan and the x to the head tilt. This provide an intuitive way of replicating the remote user's head on the robot without the need for manual operation.

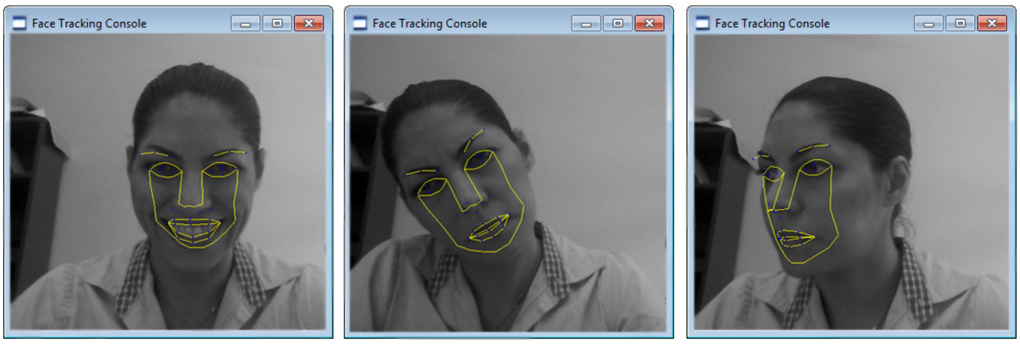

Figure 4.7: A series of head tracking snapshots showing different head orientations and pose tracking. The software tracks the location and orientation of the user's face with respect to the cameras

[1] Seeing Machines, faceAPI, http://www.seeingmachines.com/

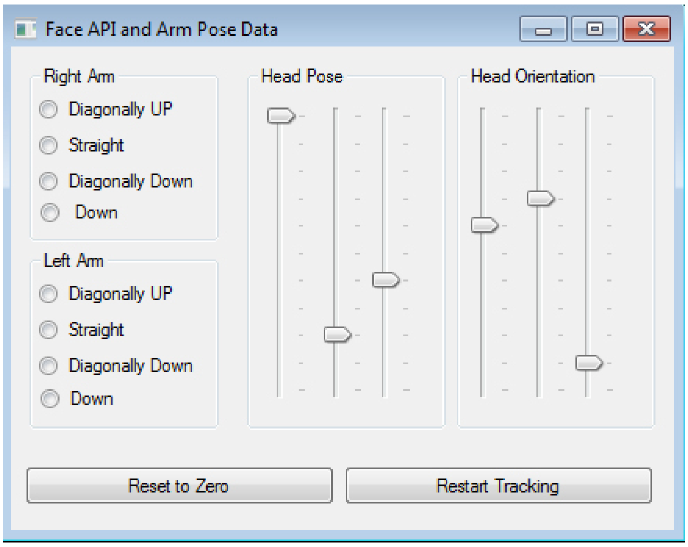

Figure 4.8: The dialog shows the data related to the head pose and orientation and facilitates robot head control

4.4.3.2 Implementation of arm gesture recognition and replication for Mini-Surrogates

The internal structure of the Mini-Surrogate, for the purpose of arm gesture replication, consists of four working servo-motors, namely the left and right arms, as well as the left and right shoulders as shown in Figure 4.13. The robot behaves based on the gesture input detected by the user's web camera, located in the surrounding space or in the user's computer.

Since our aim is developing a technology probe, our priority is choosing a rapid prototyping method with minimum cost that uses only a basic camera and can be implemented rapidly. Therefore, we avoided using Kinect, or any other gesture recognition sensor, or complex machine learning algorithm. Instead, we used a simple reliable and open source algorithm that is based on histograms and statistics. To achieve that a computer vision based arm gesture control interface is implemented using Visual C#, which analysis horizontal and vertical histogram of the video frames for detection of movements related to the hands. The algorithm provides a robust detection with little sensitivity to lighting, distance from the camera and overall the quality of the video.

The step by step description of the algorithm is as follows:

The gesture recognition module identifies data related to the movements of the robot's arm. The arm movement recognition can detect the following eight poses for each arm, which corresponds to 16 gestures.

- Raised diagonally up
- Raised straight
- Not raised
- Raised diagonally down

Initially the arm region will be detected by adaptive background subtraction (for updating the background) and then the waving motion will be recognized based on the existence of information of different region of the images and the sequence of their appearance.

In background subtraction, using difference filter the object extraction is performed and the object will be separated from the background scene. Then the difference image is threshold, in order to classify pixels to two groups of substantial change referring to moving object and minor change, which refers to the background. After thresholding, using opening filter any potential noise is removed, so that we have an image which shows the motion (user's body) area 4.9.

Figure 4.9: Background subtraction and thresholding step in arm gesture recognition

Since there is the possibility of minor changes in the background during the interaction and getting frames that include objects other than human body the background update is needed. The minor changes could be variation of light condition, appearance of small objects, etc. In this stage the initial frame, which was identified as background is updated.

Adaptive background implementation involves finding the biggest object in the image and if it was not considerably big (smaller than $20 * 20$) adding it to the background and updating the background image. Filter is for replacing the background image with the new frame with slight changes. When we could identify the human body as an object, we can move forward to analyzing the gestures. However, to proceed with detecting the arm gestures the sub-regions that are occupied by arm blocks should be identified first.

Arm blocks are identified by analyzing object both vertical and horizontal histograms of the image as shown in Figure 4.10.

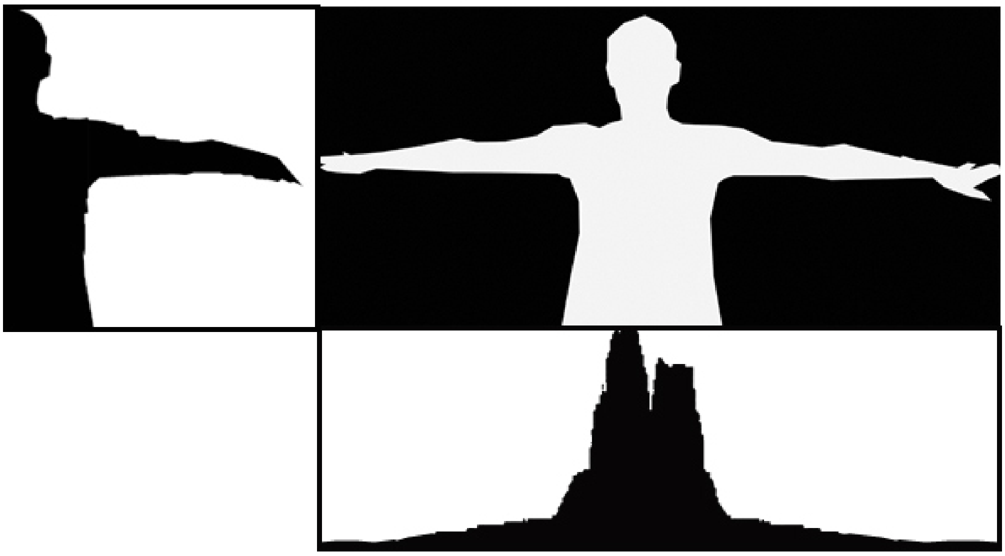

Figure 4.10: Horizontal and vertical histograms are needed to be further analyzed in order to identify the arms and their gestures

In order to achieve that horizontal histogram is used to separate the hand area from upper body area by applying the threshold coefficient value of 0.3. This is based on the fact that human hand thickness is less than 30% of the height of torso. Then the hand's length and the upper body width should be figured out from the threshold horizontal histogram. The width of empty area on the right of the histogram is equivalent to the length of the right hand and the length of the left hand is the empty area on the left of the histogram. The area between the blank areas is the upper body width as shown in Figure 4.11.

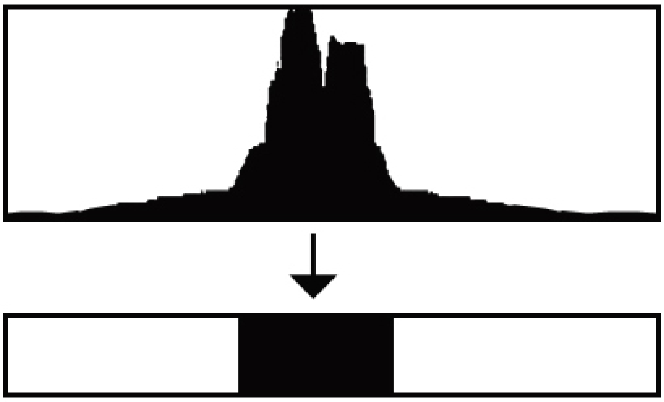

Figure 4.11: The area between the blank areas represents the width of torso

Up to this stage we know the hand length and the upper body width. Using the body proportions and statistical assumptions we can say the hand is raised or not. After that can figure out if it is raised diagonally up, raised straight, or raised diagonally down. In case that the hand is not raised, its width on the horizontal histogram should not exceed 30% of the torso's width. So, if it exceeded 30% it means that the hand is raised and the direction should be recognized.

In order to recognize the direction of a hand which is raised initially a pre-processing is performed. The pre-processing is applied to remove possible noises and shadows from the image. After getting a noiseless vertical histogram the following approach is taken to detect each of the classed including: straight hand, hands up and hand down as shown in 4.12

As can be seen from the histograms in the diagonally down hand the pick of the histogram is shifted near the centre, the pick for diagonally up hand is near the beginning of the histogram and for straight raise hand the pick is thin and

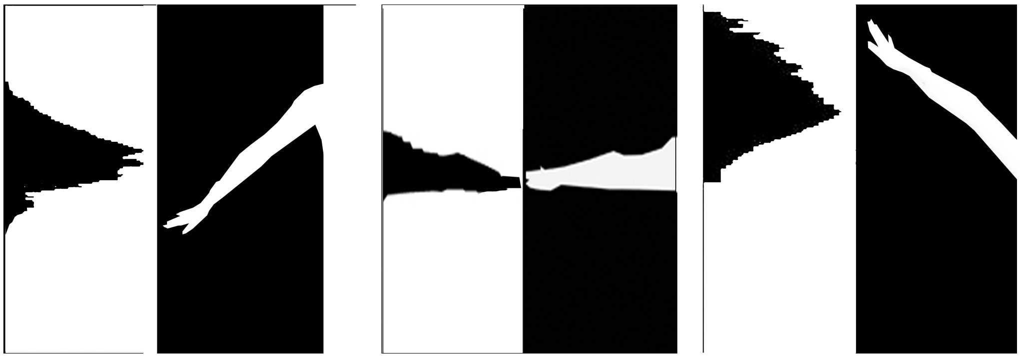

Figure 4.12: The histograms related to different classes of raised hand gesture

high (this is because hand width is much smaller than its length). By finding the histogram pick each of the above hand positions could be identified. So, by having 4 hand position in each hand we can recognize $2^4 = 16$ hand gestures.

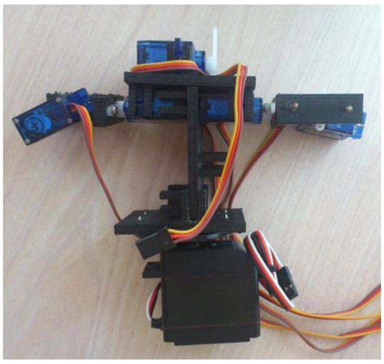

Figure 4.13: Abstract model for testing gesture based control

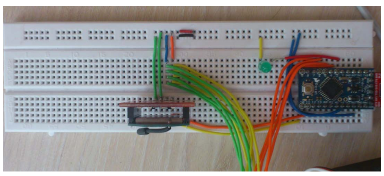

Figure 4.14: Xbee module used for wireless communication.

The information values corresponding to the hand gestures are then communicated to the device serially via a wireless module, which enables the specific motors of the Mini-Surrogate to perform the required gestures, as shown in Figure 4.5. The servomotors are designed to go through a maximum angle of 130 degrees. The application implemented to, communicates with the Arduino's XBee 4.14 by setting up a wireless connection. Once the connection is made, the required data are transferred to the Arduino module which processes it and sends the replication related parameters (angle and speed) to the respective motors. The selected motors use the received information to perform the required movement and replicate the gestures performed by the user.

In order to evaluate the performances of the developed arm gesture control algorithm, the method was tested by 8 untrained users (4 males, 4 Females with different body sizes). During the test the lighting and the distances from the camera were kept approximately constant. Each user tried all 16 gestures. The average rate of successfully performed actions by the robot was 97.6%.

4.4.4 Evaluation of the user's perception on personalized telepresence agents

Referring to three features of physical embodiments, nonverbal behaviors (gestures and proximity), and enclothed cognition, we have proposed embodied telepresence robots as a medium for remote telecommunication. Former studies have found the merits of physical embodiment in communication by comparing virtual and physical avatars [185] as well as nonverbal behaviors through comparing static and expressive robots [43]. However, the use of enclothed cognition in the design of telepresence robots is still unexplored.

Our aim of experiment was two fold:

- whether or not making telepresence robots similar to the person they represent, in terms of appearance, can enhance the affectivity of remote communication. In other words, the question is, would the users experience more emotional engagement with their partner, while communicating through a personalized robot or not. To test this, we conducted a *between subject* [2] study with two conditions of personalized and generic robots. In personalized robots condition, two customizable robots were prepared to represent either sex (Female/Male) and were customized by ourselves referring to the participants' photos using accessories, wigs, and masks to look like them. In the experiment with generic robots, the robots are a very simple programmable humanoid robot without any attire, accessories, hair or facial mask.
- What are the users' design expectations from a robotic interface which targets intimate telepresence.

In both parts of the experiment, the robots could reproduce the same body languages. These body languages included nodding, waving, moving back-

[2] In a between-subjects design, the various experimental treatments are given to different groups of subjects. In this study one group interacted with the personalized robots and the other group interacted with the generic robots.

ward, moving forward, and turning. Therefore, we could monitor the effect of appearance as an independent variable. The participants' feedback was collected through questionnaires and an open ended question asked about their overall experience and expectations at the end of the form.

4.4.4.1 Participants

A sample of couples were recruited from the student and staff body of National University of Singapore (N = 36). Two couples (four participant) each from one experimental condition, were dropped from the initial sample due to the technical failure that happened during the control of the robots and setting up the experiment. The final sample (N = 32), ranging in age from 22 to 34 (mean age = 27.5, SD = 3.13) with the previous experience of being apart for at least 6 months (mean = 12.3 months, SD = 7.23) and in a relationship for at least one year (mean = 3.3 years, SD = 2.23) were selected.

4.4.4.2 Design

A two-condition, between-subject design was employed. Participants were randomly assigned to interact with personalized (n = 16) or generic (n = 16) robot condition. Explanatory variables were the robot appearance (personalized vs generic), gender, age, duration of the relationship, and duration being apart. We adopted a similar approach used in past questionnaires that were designed to extract subjective responses to mediated communications [118]. The user's perception on the quality of the communication of Mini-Surrogate compared to the generic robot was evaluated through the post experiment questionnaire and rated on a seven-point likert scales ranging from 1 (totally disagree) to 7 (completely agree) after the experiment.

4.4.4.3 Procedure

The experiment took almost one hour per couple to complete and took place over a four day period. It included questionnaires with an open-ended question at the end of the personalized robot users forms. Initially, users were briefed about the scenario and how to interact with the robots. Each couple performed the experiment together, while they were siting in different partitions and could not directly see or hear each other. To ensure the real-time channeling between conversations and the body languages generated by the robot, one of our team members was controlling the surrogates by a wizard of oz mechanism (teleoperation mode of the contorl) and could hear the conversation between couples to operate the robots accordingly. The users were aware that their conversations could be heard.

It should be noted that these telepresence robots are not developed for the purpose of conversation or information exchange. They are mainly proposed as a basic platform for intimate interactions and this chapter explores their design properties from the user's point of view. However, in this specific experiment, in order to test the effect of personalization in the controlled environment the experiment is performed in the context of conversation. In the conversation scenario, even a very short delay between the conversation and body languages could be distracting Therefore, to avoid this issue the wizard of oz mechanism is used. Although, current gesture recognition and reproduction works properly for its designed goal in this research, real-time channeling between conversation and robot gestures is still beyond the state of the art and is not the focus of this research.

4.4.4.4 Apparatus

The apparatus of the user study consisted of four telepresence robots, a pair of personalized male and female robot, a pair of generic robot, wigs, masks, and accessories. All of the robots could reproduce identical gestures and body languages including moving forward and backwards, turning, nodding, and waving.

4.4.4.5 Analysis

Since our data was normally distributed (see Figures 4.15 and 4.16) $Z_{Skewness.generic}$ = 0.75, $Z_{Kurtosis.generic}$ = 0.55 and $Z_{Skewness.personalized}$ = 0.85, $Z_{Kurtosis.personalized}$ = 0.02 and Equality of variances was established (sig = 0.09 > 0.05) we used the two-tailed unpaired t-test with the alpha level of 0.05 and confidence interval = 95%.

The perceived affectivity of the interactions were determined by calculating the mean of each participants total score. Lower scores on this scale represent lower perceived affectivity, and higher scores represent higher perceived accountability. Participants perceived affectivity ratings ranged from 1.94 to 5.88 and the internal consistency of the scale was acceptable (*Cronbachsalpha* = 0.98). There was a significant difference in the scores for generic (*M*=2.62, *SD*=0.42) and personalized (*M*=5.45, SD=0.28) conditions; $t(30)= 22.45$, $p = 0.00 < 0.05$.

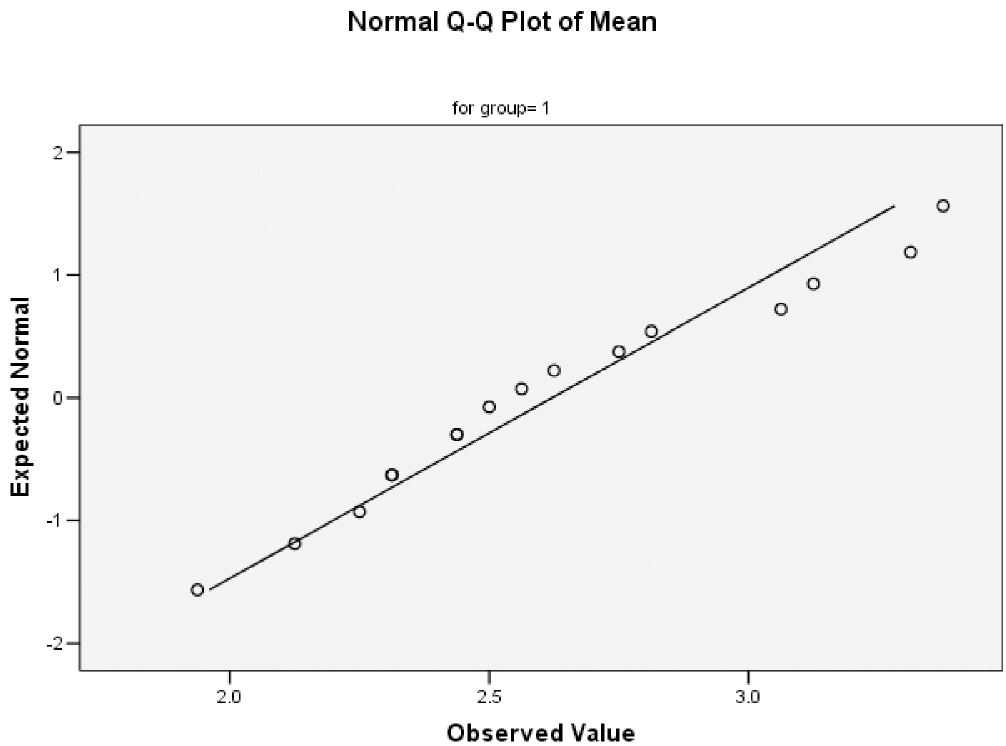

Figure 4.15: The diagram shows that the data from generic robot users is normally distributed

Since there might be the doubt on possibility of dependency between the ratings of each couple, we have also reanalyzed the data by combining the result

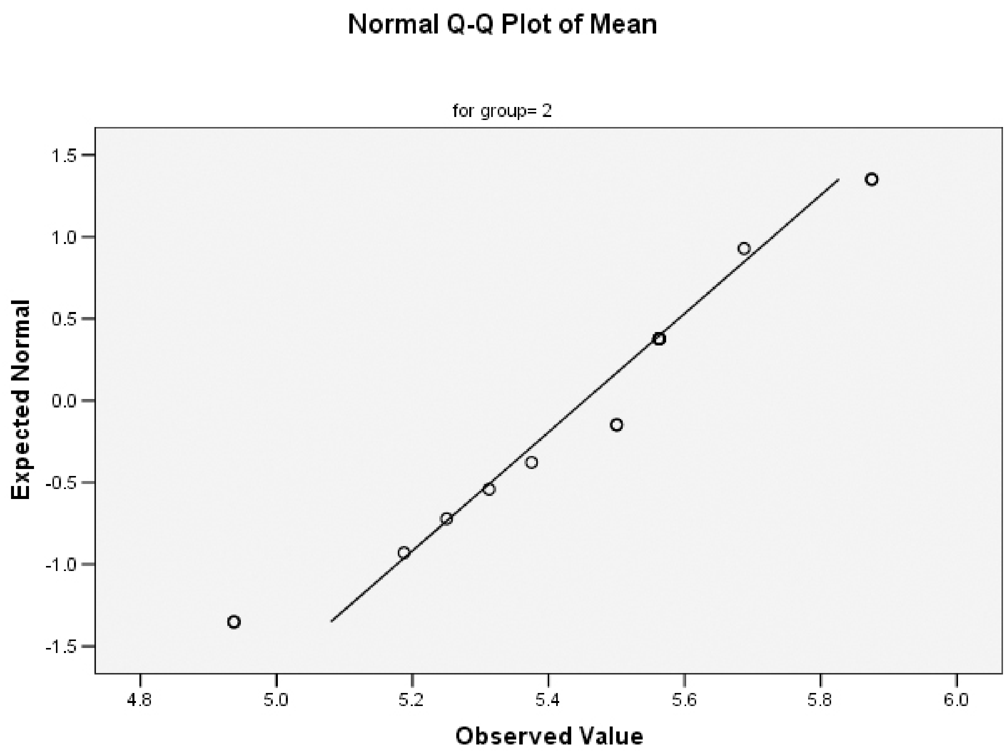

Figure 4.16: The diagram shows that the data from personalized robot users is normally distributed.

from each couple together and considered each couple as one sample. After converting each couples' data to one, we had a sample size which was half of the previous analysis. Therefore, nonparametric Mann whitney u test is performed and the p value is 0.00 < alpha (0.05), which reject the null hypothesis and suggest there is still significant difference in the perceived affectivity of each group.

We were also interested to know the effect of other explanatory variables in the perception of affectivity among the personalized robot users. After testing the normality of distribution, we performed the 2 X 2 between-subjects, factorial design two times. First we considered age and gender as independent variable

(IV) and second time we tested duration of the relationship and duration being apart. The dependent variable was the perceived affectivity at all the conditions. 28 years old of age, 9 months of separation, and 2 years for length of relationship were chosen as cutoffs to classify them to groups of young adults and adult, acceptable and long duration of separation, and newly married and stabilized relationship.

The 2 X 2 between-subjects analysis of variance (ANOVA) revealed that there was not any significant difference between male and female perception $F(1, 12) = 3.84$, $MS_e = 0.06$, $p = 0.07 > 0.05$ as well as different age classes (above and below 28 years old) $F(1, 12) = 0.24$, $p = 0.63$. Also the interaction of age and gender $F(1, 12) = 1.50$, $p = 0.24$ did not have significant difference between two gender and age classes.

The second 2 X 2 between-subjects analysis of variance (ANOVA) also showed that duration of relationship and duration being apart did not contribute towards the perception of affectivity. The users were divided to four groups based on being apart (below and above nine months) and duration of the whole relationship (below and equal two years and above two years). IV = duration of the relationship: $F(1, 12) = 0.015$, $MS_e = 0.087$, $p = 0.9 > 0.05$. IV = duration being apart: $F(1, 12) = 0.23$, $p = 0.62$. Interaction of both IVs: $F(1, 12) = 0.06$, $p = 0.4$.

Regression analysis is also performed, to ensure that the perceived affectivity is not related to the parameters of age, sex, duration of the relationship and duration that they have been apart. As can be seen is Table 4.1 the p values obtained from all of the above mentioned parameters are more than 5% which, means the null hypothesis cannot be rejected and there is no effect of age, duration of the whole relationship, duration being apart and gender of the participants on the perception of affectivity.

Coefficients (a)

Model	Unstandardized Coefficients		Standardized Coefficients	t.	Sig.
	B	Std. Error	Beta		
(Constant)	5.187	2.651		1.956	0.061
Age	-0.038	0.097	-0.080	-0.390	**0.700**
Relationship Duration	-0.025	0.199	-0.037	-0.124	**0.902**
Duration Being Apart	-0.024	0.062	0.119	0.393	**0.698**
Gender	-0.2.16	0.557	-0.074	-0.387	**0.702**

a.Dependent Variable: Mean

Table 4.1: Multiple regression results on the influence of other explanatory variables including age, duration of the whole relationship, duration being apart and gender on the perceived affectivity.

At the end of the questionnaires which was given to the personalized robot users we asked an open-ended question regarding their other expectations from the robot and their overall experience, which was not included in the current prototype. Generally, the responses of a majority of the users was positive towards the Mini-Surrogate concept. Six subjects reported their positive feeling about using the robot as their intimate partners depend on the similarities between their partner and the robot. They gave detailed opinions about their desired form factor and functional properties of the personalized robot. For instance one said: "My wife has the habit of blinking regularly when she talks about an emotional content therefore, I would like that the robot could also do the same." Another subject pointed that her boyfriend usually uses a specific perfume when he is dressed up and she was expecting the same thing from the robot. Another one was saying “ We usually kiss when we greet each other, but the robot extended her hand to shake hands, which was different from what I expected.”

Four subjects mentioned they would rather be more intimate with their partners’ surrogate. One subject said: “If the robots material was soft or sponge like, it could be more huggable.” Another said he would rather see her girlfriend’s robot in mini dress instead of a hat and fully covered dress. Another pointed: “I would like to be able to touch the robot and my boyfriend feels my touch at the same point.” The other one mentioned she would like to feel the eye contacts. The answere of the rest of the users mainly referred to the need for facial expressions.

In general, we received positive responses when the participants were asked if they would be willing to use a similar system when they are apart. Although the responses were given in a positive tone, yet it highlights a potential issue about the adaptability of Mini-Surrogate in human society. Even though the robots were developed to enhance telepresence and emotional communication over long distance, the question of “Will such systems really fill the physical void created by physical absence or not?” is still worthwhile to be investigated more.

4.5 Summary

The concept of enclothed cognition and perspective of telepresence robots as mediators of interpersonal communication were explored. Then the design philosophy and the process of personalization and development of minimally expressive pair of telepresence robots were described. The goal was to provide a medium to act as a remote person's representative to be connected, aware and to interact expressively while people are apart. Therefore, a pair of robots were built to ask specific questions about the effects of reproducing the likeness of a remote person and enabling them to provide us with their desired nonverbal cues that facilitate the expression of their emotion while remotely located. In spite of the robot's restricted functionality, low fidelity prototypes assist design collaborations as a participatory design instrument (see [132] for the details). A participatory design method using abstract robots facilitates finding the user's expectations toward the system for each given usage context. It helped us to discuss the basic form factors, communication, and movement parameters in participatory design.

First iteration was paper sketches as a result interface with natural form factor similar to human and with portability was decided. Based on the feedback from in the first iteration, portable size lifelike exact copy of two team members were developed. Then the 2nd one was used in concept assessment and feasibility study. As a result likeness of the robot received positive feedback, but customizability was required. In the third version again result of second iteration was used and the robots were made more customizable and also sizes were increased to be able to accommodate the internal circuits. This third prototype, which was a medium fidelity prototype, was used to test the possible influence of personalization on affectivity and exploration of the design space. Therefore, the prototypes gradually improved from a very high level concept to tangible interfaces that could easily engage the users in design space exploration. Now, that the design space is explored we have design framework resulted from a user centered design process. This framework could be used in collaboration with industrial partners to be commercialized and develop high fidelity prototypes.

We conducted an experiment to evaluate the perceived affectivity of the Mini-Surrogate robots in enhancing the quality of communication. In this experiment, Mini-Surrogate was compared against the simple generic robot and the significant difference in affectivity was perceived. The findings are also inline with the media equation theory [209]. According to the media equation "people react to the media in the same manner that respond to other people in daily social interaction." For instance, people are attracted to other people whose personalities are like themselves." This might suggest that they probably would respond to their partner's surrogate in the same way that they respond to their real partner.

Up to this step of the study, it was concluded that the Mini-Surrogate telepresence robots could potentially facilitate expressive communication. However more intimate nonverbal signals were required to be reproduced to facilitate a more intimate experience. Research on creating a more customizable and refined prototype with multiple sensory feedbacks is suggested for further studies. More work must be done to produce a technically mature interface to aid the actual use of such underutilized but potentially useful communication medium. The findings from this chapter could be used as a guideline for designing more embodied telepresence agents for mediating intimacy, which was pointed as a research gap in problem one (1.2).

Two main issues, which need improvement were discovered during this outside-inwards prototyping practice. One is about the multiple sensory feedbacks and another one about the behavior control and functionality of the system:

- The physical avatars have lots of potential for mediating intimacy. Physicalness enables the medium to have effects on the environment and people, such as moving objects or touching other entities in the environment. Up to this stage not much benefit was taken from the physicalness of the prototypes. The only merit of the physicalness which was applied in this study was the spatial dimension and tangibility, which are limited in virtual forms. Haptic feedback from the agent could address this issue.

- The second major issue faced was about the control mechanism of the telepresence robots. In the current prototype the gesture recognition technology was used to detect the body languages. There are two issues with this approach, One is that both users need to be available in front of the camera to be able to use the system. The other one is that there would be a lag between the user's body languages and the surrogates mimics on the other side. This could minimize the practicality of the system. To address this issue an AI model is to be introduced to infer the user's state through the smartphone and generate the appropriate behavior for the robot accordingly. Smartphone is chosen, since it is widely and frequently used in the contemporary society.

The following two sections describe two studies one on the controller or AI module of the system and the other one on haptic feedback by teleporting kisses.

Chapter 5

Modeling Smart Affective Telepresence Agent

5.1 Second level of modeling: Artificial intelligence (AI) model for affective telepresence

From the previous experiments, it was learnt that control mechanism of the affective telepresence robots needs to be improved. One reason for this decision was maximizing the intuitiveness and opportunities of the connectedness by automatic behavior generation. Gesture recognition based approaches for telepresence, regardless of their challenges in robust recognition and can only work in online mode. To facilitate connectedness in off-line mode where both users cannot be simultaneously available, an AI model is developed, which is the main focus of this chapter. The AI module performs the following actions:

- Infers the stochastic mood state of the active mobile users based on the smartphone data.

- Generates expressive behaviors such as the facial expressions and body languages corresponding to the estimated mood state through a synthetic agent.
- Expressing mood transitions based on the personality types
- Generates feedbacks to the mood, behavior and context of the local user on behalf of the remote user.

5.2 Design considerations

One important issue during communicating through the current telepresence technologies is the need for availability of both interacting parties. This is opposed to the need for ongoing connectedness in intimate communications [2]. To support connectedness in off-line mode we introduce a novel AI model for control of the robot body languages and the generation of the facial expressions in the absence of the real user.

5.2.1 Ongoing connectedness using smartphone

Establishing and maintaining the possibility of communication is one of the essential requirements of phatic communication. Therefore, we applied the smartphone as a platform for the perception system. In 2012, the number of smartphone users crossed the 1 billion mark globally, and by the end of 2014, that number would be more than 1.75 billion [1]. Whether used for the basic need of communication or for entertainment, smartphones have become an indispensable part of daily lives of almost a quarter of the world's population. The majority of this quarter of the world's population, use social media networking applications such as Facebook or Twitter to communicate to a large audience, and the pervasiveness of such social media corroborates the idea that these smartphone users have the desire to communicate their thoughts, emotion and their mood to other people.

The smartphone is able to sense and log various behavioral data such as the user's location, communication data, scheduled events, operational status, movement patterns, usage information and more. This broad spectrum of users' data, might support the inference of high level user status. Unlike the obtrusive applications, which require the user to input his/her status, the smartphone has enabled the development of unobtrusive applications, which run in the background and are able to infer high level information about the user. With this as an impetus, we choose the smartphone sensor as a tool with the potential to maximize the awareness of the user's mood.

Therefore, considering the wide and the constant use of the smartphones and their potential in detecting the user's state, it could be a suitable platform for affective and behavioral state detection. However, since the smartphone

[1] http://www.emarketer.com/Article/Smartphone-Users-Worldwide-Will-Total-175-Billion-2014/1010536

environment is uncertain, noisy, and changes rapidly, the perception system should be able to handle these uncertainties [210]. In this study, we propose a solution that performs high-level mood sensing through the smartphones and handles these uncertainties.

5.2.1.1 Related works on smartphone-based high level sensing

Smartphone-based high level sensing recently has attracted the attention of researchers and early examples of smartphone-based activity sensing in a wide variety of applications are emerging. For example, health and persuasion as in *UbiFit* that measures the activity level using the accelerometer for an exercise motivational app [211]. Social networks as in *CenceMe* that leverages on the user's activity and social interactions using the accelerometer and microphone and updates their presence status in their social networks accordingly [212]. Environmental monitoring as in *PEIR* that uses smartphone sensors to detect transportation modes of the users and create personalized environmental impact report [213]. Transportation management as in *VTrack* that is a system for using mobile phones to accurately estimate road travel times [214].

There has also been several attempts in smartphone-based activity detection from perspectives other than the application point of view. *Jigsaw* [215], is a continuous sensing engine that supports continuous monitoring of human activities and context. The focus of this study has been on phone resource management and battery usage. A variety of classification techniques are proposed to detect the type of activity (i.e. running, walking, standing, stair climbing) for instance in [216, 217, 218] and many more. While the research space in smartphone sensing is largely populated by technologies targeting behavior inference, very few studies have focused on leveraging affective state. Researchers in affective state detection have mainly focused on audio and video based emotion recognition (i.e. *EmotionSense* [219]). The closest works to our research that have focused on analyzing the collective set of smartphone sensor's data for affect recognition are *MoodScope* [220] and [221].

The mood inference approach in *MoodScope* is based on supervised learning and needs training and labeling. This approach is based on learning behavior journals and smartphone usage history, to find the change patterns of raw data and associating them to high level data. The training procedure needs the users to log their mood status, which puts a lot of burden on the users. Moreover, the generalizability of the collected data to new users is not addressed. Therefore, personalized training or data collection from a large and diverse population is required. Besides, since the smartphone environment is dynamic and uncertain the probabilistic models of machine learning are more suited to this application. The second closely related to our work [221], has tried to address the following two issues by proposing probabilistic inference modeling by Bayesian Networks (BN). However, there are a few gaps in this study in terms of affect sensing that is addressed in this dissertation. The mood history of the user or the effect of previous mood state is not considered in their design. The visualization of the agent affective state is very basic and without corresponding facial expressions. Moreover, the application developed for this model is a personalized digital assistant service that makes it totally distinct from the main goal of our study.

5.2.2 Attribution to the user

In order to maintain the intimate bonds, our goal is to have an agent, which could be perceived as a natural extension of the remote person, and not merely an artificial agent that acts as a mediator. In intimate telepresence technologies, one of the design approaches to achieve this goal is attribution to a remote partner. In the initial model, we have studied the effect of attribution to the user on intimacy, by customizing the robot appearance. It was done by making robots that look and dress like the persons they represent. In this study, we want to increase the agents likeness by attributing their personality to the persons that they represent.

The importance of attribution to the user has been studied by other researchers, mainly by focussing on the appearance of the media and the form factor. For instance, a study on telepresence through the transition of heartbeats suggested that heartbeat can be perceived as an intimate signal provided that it is associated to the remote partner [90]. In another study on intimate telepresence through mediated hand holding, artificial hand prototypes had personalized appearance for each couple instead of a standard form factor. The hand prints of couples and sleeve pattern were used in the design of the hands to promote intimate telepresence through attribution to their owners [107]. *Magic sock drawer*

[146] which supports serendipitous sharing of hand-written notes and the attribution to the user is achieved by communicating the unique hand writing of the sender. However, to the best of our knowledge, there are not many attempts in intimate telepresence technologies through attribution of the remote user's personality type to the media. Giving personality to the robot could also enhance the naturalness and believability of the robot [222]. Therefore, it might consequently convey the illusion of non-mediation and sense of co-presence.

5.2.3 Overall architecture of the smartphone-based affective telepresence system

The system is composed of a pair of telepresence robots, two smartphones and a server. As illustrated in Figure 5.1, sensing is done using the smartphone sensors, then the acquired data are analyzed in the server and as a result corresponding actions are generated and visualized through the agents in the remote location. Performed actions are decided using the behavior network which will be explained in the following sections. The main difference between this architecture and conventional cognitive robotic systems is that the action happens in the remote location (in relation to the sensors) for the purpose of telepresence.

5.3 Affective behavior generation system

Affective behaviors are an embodied reaction of pleasure and displeasure, which are influenced by personality, mood, emotion and many other internal and external factors. While emotions are very short term affective states, moods change

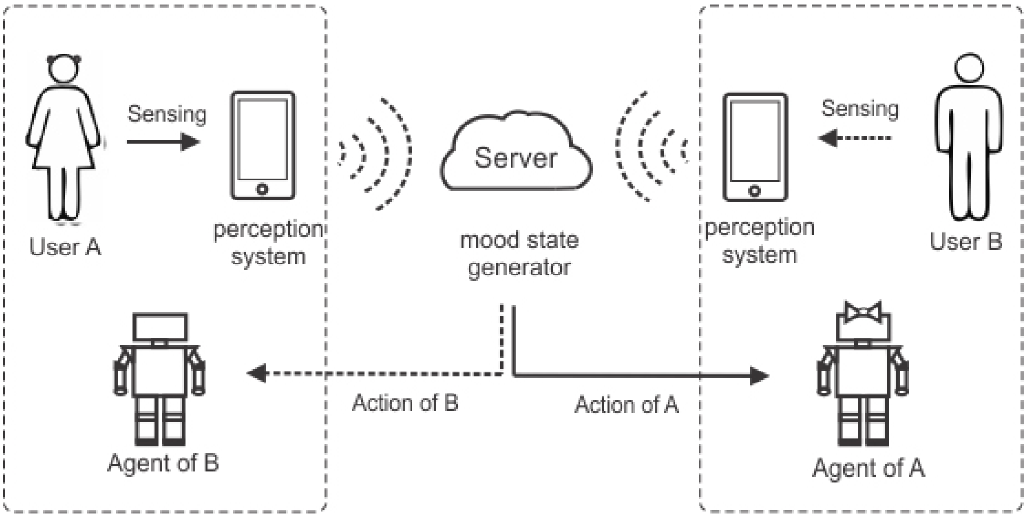

Figure 5.1: Overall Architecture of the proposed affective telepresence system

slowly, [223]. In this study, we have chosen to focus on affective behavior generation on behalf of a remote user, considering her/his personality type. By inclusion of the personality we can relate mood state transitions to the personality type of a remote partner, and as a result attribute the agent's behavior to the partner.

The agent will generate three types of behaviors:

- Imitation of the remote partner's mood through facial expressions and body languages.
- Express feedback to the user's mood state (on behalf of the remote partner), considering the remote user's personality. For instance, cheer up the local user, when the user is sad, mirroring the local user's mood when is happy. More detail is shown in 5.8
- Express time based behaviors (on behalf of the remote partner). For in-

stance, saying good morning when the local user's time is morning.

To identify the personality type, the *big five personality* model is applied [224]. The big five personality model is a framework to determine the personality type of a person at the broadest level of abstraction. This model has received substantial support in psychology [225]. The five models of personality consist of extraversion (E), agreeableness (A), conscientiousness (C), neuroticism (N) and openness (O).

As shown in Figure 5.2, the valence−arousal two-dimensional space model [226] is used to generate the mood state of the users. The horizontal axis is arousal which ranges from displeasure to pleasure, and the vertical axis is valence, which infers the user state from calm to arouse. The figure shows nine basic emotion coordinate in 2-D valence-arousal plane. And an example of a mood changed from t to t+1, calculated based on the designed dynamic bayesian network (DBN) model is illustrated in Figure 5.2. Linear regression is utilized to reveal the mood state and its transitions between sad, bored, sleepy, relax, happy, delighted, aroused, alarmed, and distressed.

Figure 5.3, shows the architecture of the affective behavior generation module of the telepresence system. The inputs of the system are the smartphone hard and soft sensory data and manual entry of the users. The low-level data from the smartphone sensors will be processed in the perception system and high-level data describing the state of the user will be recognized. The high-level data which

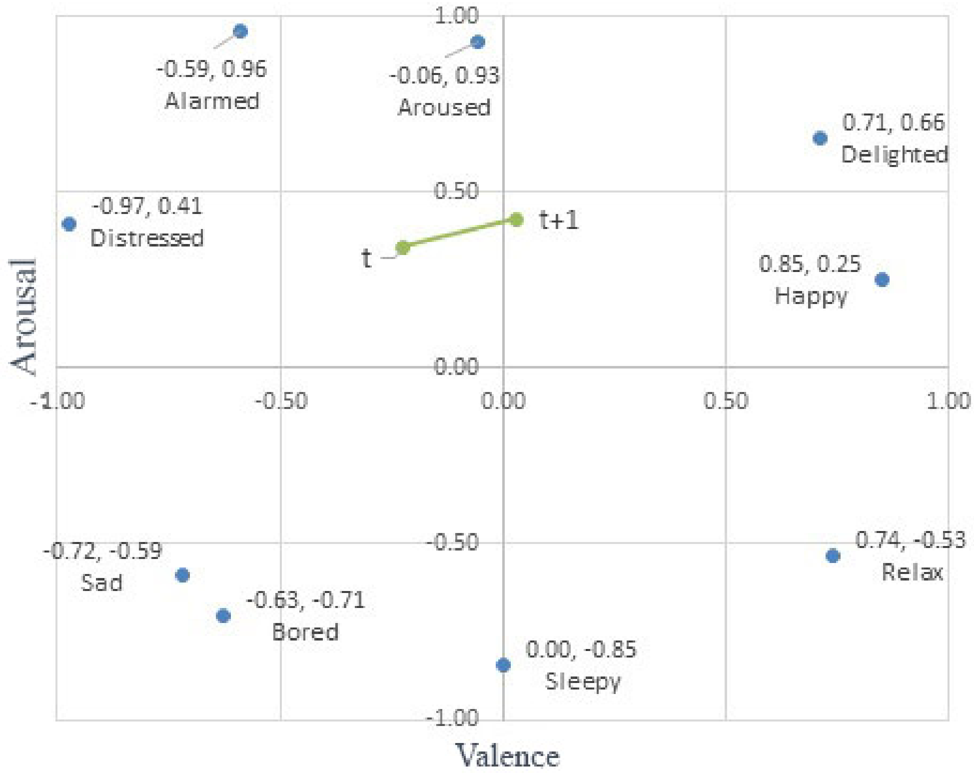

Figure 5.2: Nine mood coordinates in two-dimensional valence–arousal plane

describe the mood state of the user are sent to the mood and gesture generation system to produce the facial expressions and body languages of the agent. Then the user facial expressions and body movements could be transmitted to a remote user in the behavior form of a robotic agent or a virtual character.

5.3.1 Smartphone sensing and perception

Smartphone contains useful data about its active users, that can be obtained through its built-in hard and soft sensors. The relevant data can be extracted and processed to infer the user's state. For instance, the user call logs can identify the number of calls, duration and the most contacted person by the user. The

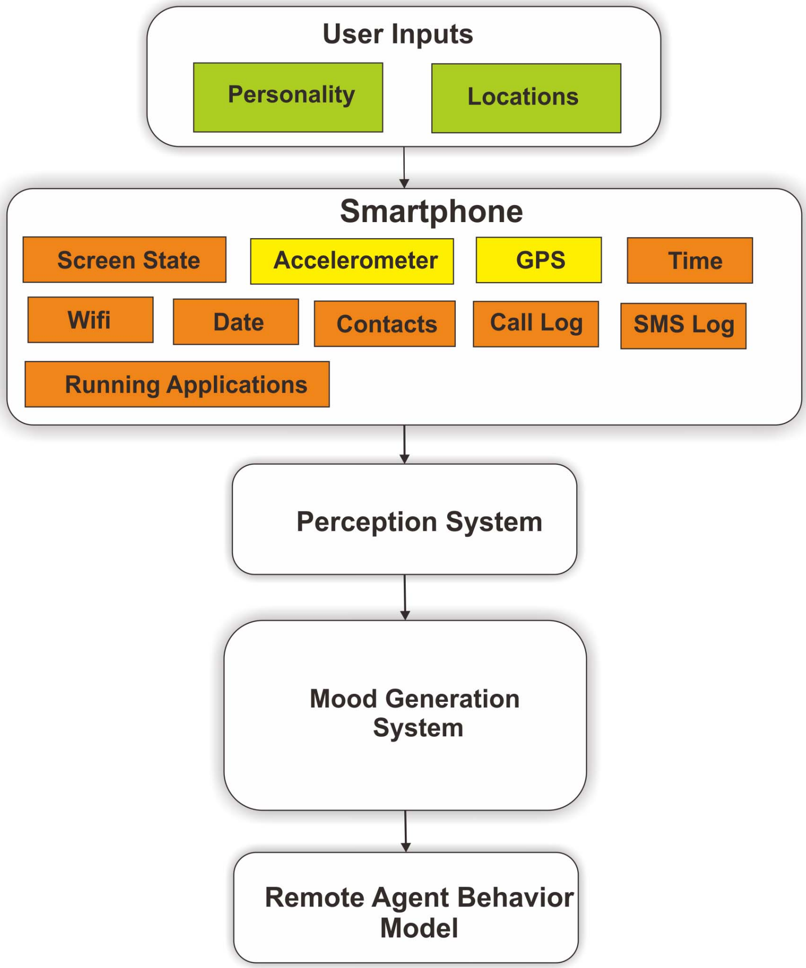

Figure 5.3: Architecture of affective behavior generation of automated telepresence agent.

running applications can identify what types of applications are used. Moreover, the GPS and accelerometer can describe the activity state of the user. Such data are useful to determine the user state such as idle or busy.

In our proposed method, in the smartphone data extraction phase, some data will be requested to be manually logged by users. The required manual entries by the users are their home and office locations and answers to the questionnaires that reveals their personality type (A).

Location labeling is done by tagging the longitude and latitude value of their home and offices, which is detected by Global Positioning System (GPS). The personality type is detectable by answering a questionnaire at the beginning of the smartphone app usage.

Table 5.3.1 describes the used sensors and their components. The automatically sensed low-level data from the soft and hard sensors combined with the manual entry of the user is gathered in the perception system.

Type	**Class**	**Components**
Hard Sensors	GPS	Latitude, Longitude, Speed
	Accelerometer	X,Y,Z
Soft Sensors	Time	Clock/Date
	Screen	State: On/Off
	Aplications	Type, Number
	Call and SMS log	Number , Name, Duration
	Wifi	Wifi name
	Date	Weekend, Weekday, Speical Day

Table 5.1: Soft and hard sensors of smartphone used in the perception system.

In this study we have focused on mood sensing. Therefore, those sensors that could be associated to the mood are chosen. These data are retrieved in real-time using “Funf” open sensing framework [227] and processed in the server.

5.3.1.1 Probabilistic mood estimation system

The main part of the mood estimation system is a dynamic bayesian network (DBN). Manual user inputs are needed to label their home and office location. *GPS* data are processed with regards to the user inputs to detect the user's *home* and *office* locations. Also, the DBN needs to know the user activity status as *idle* or *Moving* as an input to the DBN model.

Accurate activity detection from smartphone is a complex topic, which is still in its infancy and is beyond the goal of this thesis. However, in this study to have a working model we have developed only a basic classifier using support vector machines (SVM), to classify the user's activity level into two levels of idle and moving.

The classifier analyzes acceleration data and recognizes the activity level. Idle refers to the stationary positions, whereas moving refers to the dynamic behaviors such as walking and running. It should be noted that there is an exception when the user is commuting (in the car, train etc.), in this case accelerometer shows moving, but the user is idle. For this issue the GPS data should be also considered to track whether there is speed or displacement of the person. When the accelerometer says the user is moving and the GPS shows the vehicle is moving then it can be concluded that the person is in vehicle and is idle.

Data collection is performed by three people to get the training data while the smartphone is located inside their pant's pocket. The participants were three graduate students aged between 20 to 25 years old. Android OS based on Samsung Galaxy Smartphones were used as a platform for data collection. First we process the accelerometer data in 0.1 seconds time frame and calculated its standard deviation which infers the user is moving or idle. The participants were required to move and be idle for 5 seconds. the accelerometer sample frequency is 60 hertz. The 5 seconds data are further truncated into 250 set data of 20ms time frame and calculated for the standard deviation of accelerometer x,y, and z data. This 250 set of standard deviation is used for the classification of moving and idle.

The data are classified using Waikato Environment for Knowledge Analysis (WEKA) software sequential minimal optimization (SMO) library, which includes the algorithm for training a support vector classifier . The resulted hyperplane (5.1) for classifying idle and moving state is shown below with accuracy of 98.8%

$$Hyperplane = 3.2797(normalized)x + 4.9479(normalized)y + 4.7079(normalized)z - 2.484 \tag{5.1}$$

Table 5.3.1.1 shows the other details related to the classification results:

Finally, the above data combined with other sensors data are analyzed using our novel designed DBN to estimate the stochastic mood state of the user. Due to the high-level of uncertainty, dynamic changes of smartphone data and insufficient data about the user, DBN is used. Bayesian Network is an estab-

Relation	Moving / Idle
Instances	1128
Attributes	[x,y,z,state]
Test mode	10 fold cross validation
Number of kernel evaluations	2293 (59.573% cached)
Correctly Classified Instances	1115,98.8475%
Incorrectly Classified Instances	13, 1.1525 %
Kappa statistic	0.9767
Mean absolute error	0.0115
Root mean squared error	0.1074
Relative absolute error	2.3304 %

Table 5.2: Details of the SVM classifier for idle and moving state.

lished formalism for inference under uncertainty [228, 221]. In BN, on the top of the network there are observed nodes, whose values are changed based on the smartphone sensor data. After that the conditional probability is implemented from the top of the nodes to the valence and arousal nodes using the chain rule. DBN will estimate the probability of nodes using the conditional probability distribution in time-series data [229]. In our model DBN is applied to model the probabilistic distribution of the mood, considering the history of randomly observed previous affective state variables $X_1, X_2, ...$ Commonly, variables are partitioned into $X_t = (IN_t, HD_t, OT_t)$, in which X_t represents the observed variable and IN_t, HD_t, OT_t represent the input, hidden, and output variables of a BN model respectively. Assuming time as a discrete variable for simplicity, the time index will be increased by one at each observation of the affective state. A DBN can be defined as a two sliced BN. The output of BN at time $t-1$ affects the estimated mood in time t. It defines $P(X_t|X_{t-1})$ with a directed acyclic graph as:

$$P(X_t|X_{t-1}) = \prod_{i=1}^{n} P(X_t^i|Par(X_t^i)) \tag{5.2}$$

where X_t^i is the *ith* observed node, at time t, and $Par(X_t^i)$ are the parents of X_t^i in the graph. The parents of a node $Par(X_t^i)$, could be in the same slice or in the previous time slice.

The nodes in the first slice of a two segment temporal BN has an associated conditional probability distribution, which defines $P(X_t|X_{t-1})$ for all $t > 1$.

Figure 5.4 shows the Probabilistic Mood Estimation (PME) module of the system, which is developed based on DBN. It infers the probabilistic position of the mood (α_k, β_k) on valence−arousal space model in each time interval.

The conditional probability value of app usage is generated from self-Assessment Manikin (SAM). The SAM is a 9-rating pictorial scale that is a nonverbal self-report measure of affective state using simple manikins pictures [230]. This method is known to be adopted in psychology study of affection. To get the valence score, a set of manikins was employed for the experiment. In this set, ratings for valence were scored from one (displeasure) to nine (pleasure). Participants were asked to perceive a virtual situation whereby they use a specific application in the smartphone and rate the situation based on the SAM valence rating system. This online survey was participated by 38 participants, and the raw result was processed such that the probability of each situation can be obtained and employed for the proposed DBN. The summary of the result is tabulated in table 5.3.1.1.

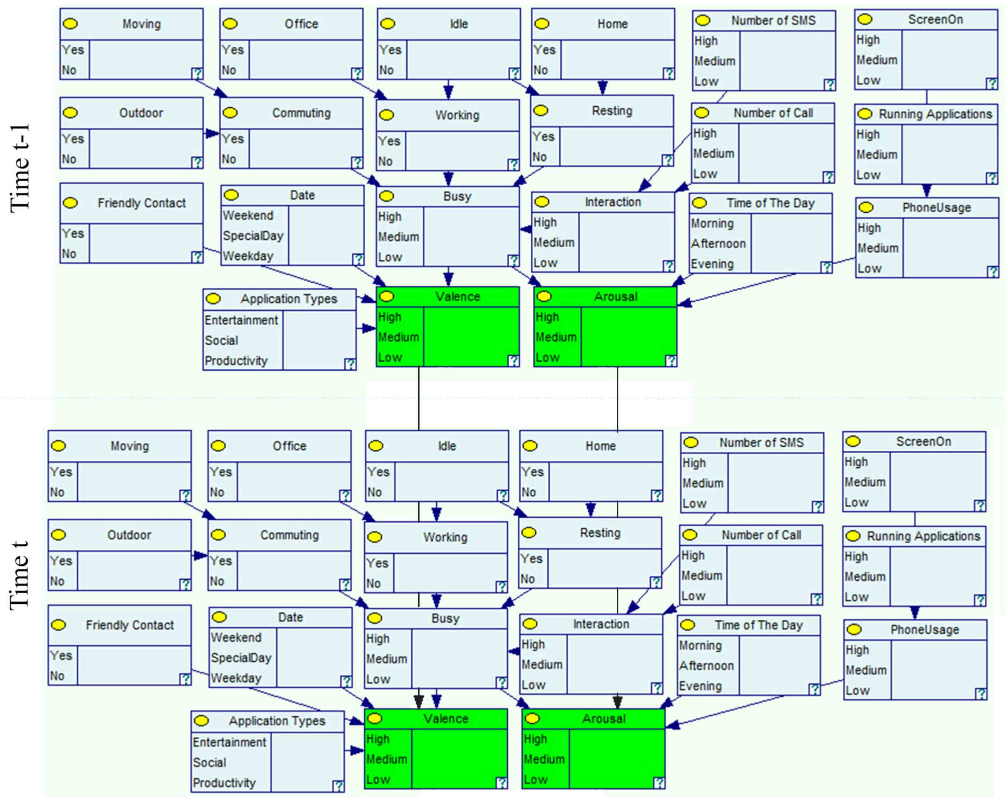

Figure 5.4: Probabilistic Mood Estimation (PME) module for inferring mood through smartphone data.

	Valence		
app Type	P(low)	P(Medium)	P(High)
Social	0,16	0,39	0,45
Productivity	0,16	0,63	0,21
Entertainment	0,08	0,39	0,53

Table 5.3: Smartphone application types and their respective valence probability

5.3.2 Remote user mood expression model of the agent

The expressed mood state on the robot depends on the agent (remote user) personality and its mood state changes on the valence-arousal space refereed by $\Delta\alpha_t, \Delta\beta_t$.

To consider the influence of the personality in mood transition, a reliable mapping method pointed in [231] is applied to relate the big five personality model and the valence−arousal plane, which results in the personality type parameters (St_α, St_β) as in equation 5.4:

$$St_\alpha = 0.21E + 0.59A + 0.19N, St_\beta = 0.15O + 0.3A + 0.57N \tag{5.3}$$

Variables E,A,N, and O are the outputs of the big five personality test, in which, "E" describes the percentage of extraversion , "A" describes the percentage of agreeableness, "N" points to the neuroticism percentage and "O" refers to degree of openness to experience . This equation translates the result of the personality questionnaire into the personality parameter. This personality parameter will be employed later to weight the mood variables on the valence ($\alpha axis$) and arousal ($\beta axis$) plane.

To express the mood transition in the agent at time t (UM_t), the manifested mood state can be calculated based on equation 5.4

$$UM_t : (\alpha_t, \beta_t) = UM_{t-1} + (St_\alpha \Delta\alpha_t, St_\beta \Delta\beta_t) \tag{5.4}$$

Where (α_t, β_t), refers to valence-arousal coordinates. This equation generates the mood transition of a remote user, considering her/his big five personality parameters.

The acquired mood state values from equation 5.4, will be utilized to classify the affective states to sad, bored, sleepy, relax, happy, delighted, aroused, alarmed, and distressed. Adopting the methodology in [232] and [233], Fuzzy

Kohonen Clustering Network (FKCN) is utilized to fuse the inferred mood states linearly and regenerate them through the agent . The obtained valence−arousal coordinate from 5.4 is passed to the input layer of the FKCN as shown in Figure 5.5. Distance layer calculates the Euclidean error distance between the input and the center of each mood (L_{ij}) using equation 5.5.

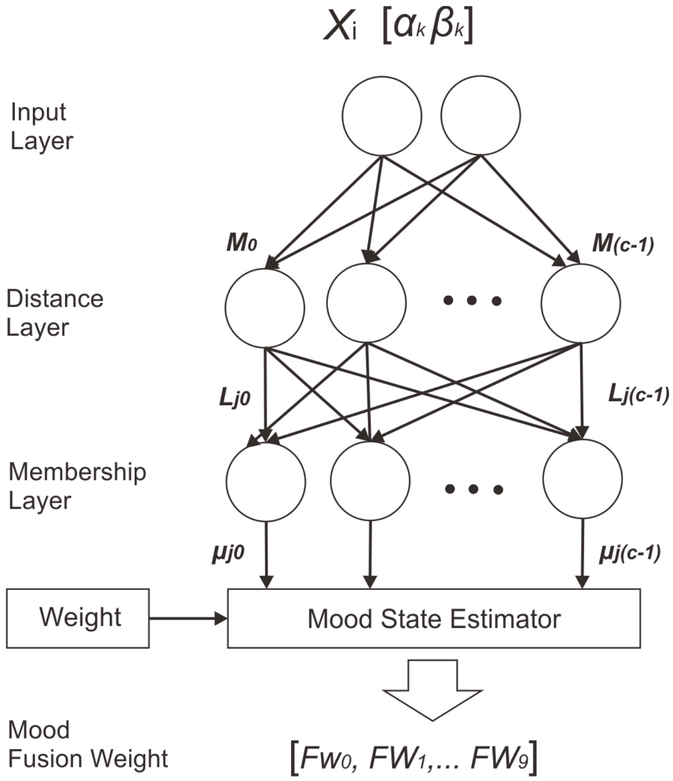

Figure 5.5: Fuzzy Kohonen Clustering Network for mood expression

$$L_{ij} : \|X_i - M_j\|^2 = (X_i - M_j)^T (X_i - M_j) \tag{5.5}$$

where X_i : (α_t, β_t) refers to the network input and M_j points to the center of *jth* emotion. The distance between these two points reflects the dissimilarity between the input and that particular mood state. This Euclidean distance error is adopted to calculate the membership value as:

$$\mu_{ij} = \begin{cases} 1 & if \quad d_{ij} = 0 \\ 0 \quad if \quad d_{it} = 0(t > 0, j \leq c-1) \end{cases} \tag{5.6}$$

where c represents the number of mood patterns;

otherwise:

$$\mu_{ij} = \sum_{l=0}^{c-1}[\frac{L_{ij}}{Ld_{il}}]$$

The sum of the membership layer is always equal to 1. The membership value, for distance of zero with *jth* mood pattern is 1, and the membership value for other mood patterns are automatically 0, otherwise the membership value is the probability of the input to be classified as a member of each mood pattern. Each mood pattern has its respective weight such as sad has weight (w) of (1, 0, 0, 0, 0, 0, 0,0,0). Finally, the remote agent behavior can show its moods as linearly combined moods as in equation 5.7

$$FW_i = \sum_{l=0}^{c-1} \mu_{ij} w_{ji} \tag{5.7}$$

where μ_{ij} is the membership value and w_{ji} is the weight of each mood pattern. Table 5.3.2 shows the emotion pattern with respect to its weight.

Mood pattern			Weight								
j	*alphak*	*betak*	*Sad*	*Relax*	*Distressed*	*Sleepy*	*Happy*	*Aroused*	*Bored*	*Alarmed*	*Delighted*
1	-0.72	-0.59	1	0	0	0	0	0	0	0	0
2	0.74	-0.53	0	1	0	0	0	0	0	0	0
3	-0.97	0.41	0	0	1	0	0	0	0	0	0
4	0	-0.85	0	0	0	1	0	0	0	0	0
5	0.85	0.25	0	0	0	0	1	0	0	0	0
6	-0.06	0.93	0	0	0	0	0	1	0	0	0
7	-0.063	-0.71	0	0	0	0	0	0	1	0	0
8	-0.59	0.96	0	0	0	0	0	0	0	1	0
9	0.71	0.66	0	0	0	0	0	0	0	0	1

Table 5.4: Mood pattern coordinates for visualization of different affective states

5.3.3 Automated mood generation module

This module is used to regenerate the mood state of a remote user in another location, via embodied robot or animated virtual agent. To evaluate the effectiveness of the developed model in the generation of the appropriate affective behaviors, an animated virtual character is simulated by adopting the Grimace model [2]. Grimace is a toolkit for researchers that supports visualization of facial expressions. The results are also visualized through a minimal robotic concept prototype by augmenting the smartphone screen on top of a humanoid robot. The simulator can express the remote user's mood using the weight values and fusion of mood expressions.

The agent will also express the mood state through hand movements. Corresponding hand movement for each state is generated using equation 5.8

$$RH_t = 0.5\beta_t + 0.5 \tag{5.8}$$

where $RH_t \in [0, 1]$ represents the agent's hand position. β_t is the user

[2] http://www.grimace-project.net/

arousal−value obtained from the mood state generator. The hand position varies from down to up with zero value represent the maximum hand down, and 1 represent the maximum hand up.

5.4 Working process of the system in mood regeneration

In order to demonstrate the working process of the system, changes of a user's mood state over a course of a day is shown based on the following scenario. The user was a 21-year-old student who actively uses smartphone for managing personal information, communication, as well as entertainment. The experiment was done on the weekday and the user was asked to manually input the smartphone data and the SAM valence−arousal ratings on each hour. Before the experiment, the user was asked to perform the big five personality test, and the user's result was 0.40 for A, 0.78 for C, 0.68 for N, 0.15 for E and 0.40 for O. From the equation , the user personality parameter (St_α, St_β) of the user is $(0.57, 0.32)$. Table 5.4 illustrates the result of the experiment made throughout a course of the day.

The data obtained from the user is processed as an input in the proposed method, and the result of the mood transition in a whole day for the user is shown in Figure 5.6.

Figure 5.7 represents the simulator and concept prototype facial and body expression for 5th, 11th and 15th mood data points from the estimated user mood state. The 5th mood is representing the agent with 62% happy, and the

Clock Time	Time	Location	Movement	Screen	Running apps	SMS Number	Friendly Contact	Call Number	V	A
07:00-08:00	Morning	Home	Idle	Low	Social	Low	No	Low	5	2
08:00-09:00	Morning	Home	Idle	Medium	Social	Low	No	Low	6	3
09:00-10:00	Morning	Outdoor	Moving	High	Entertainment	Low	Yes	Low	5	5
10:00-11:00	Morning	Office	Idle	Medium	Productivity	Low	Yes	Low	4	6
11:00-12:00	Morning	Office	Idle	Low	Social	Medium	No	Low	7	7
12:00-13:00	Afternoon	Outdoor	Moving	Medium	Entertainment	Low	Yes	Low	8	8
13:00-14:00	Afternoon	Office	Idle	Medium	Productivity	Medium	No	Low	5	7
14:00-15:00	Afternoon	Office	Idle	Low	Social	Medium	Yes	Low	2	7
15:00-16:00	Afternoon	Office	Idle	Low	Entertainment	Low	No	Low	3	7
16:00-17:00	Afternoon	Outdoor	Moving	High	Social	Low	No	Low	3	4
17:00-18:00	Afternoon	Outdoor	Moving	High	Entertainment	Medium	Yes	Low	3	4
18:00-19:00	Evening	Home	Idle	Medium	Social	Low	No	Low	6	3
19:00-20:00	Evening	Home	Idle	Low	Social	Low	No	Low	7	2
20:00-21:00	Evening	Home	Idle	Medium	Entertainment	Low	Yes	Low	7	1
21:00-22:00	Evening	Office	Idle	Low	None	Low	No	Low	7	1

Table 5.5: User valence-arousal probe

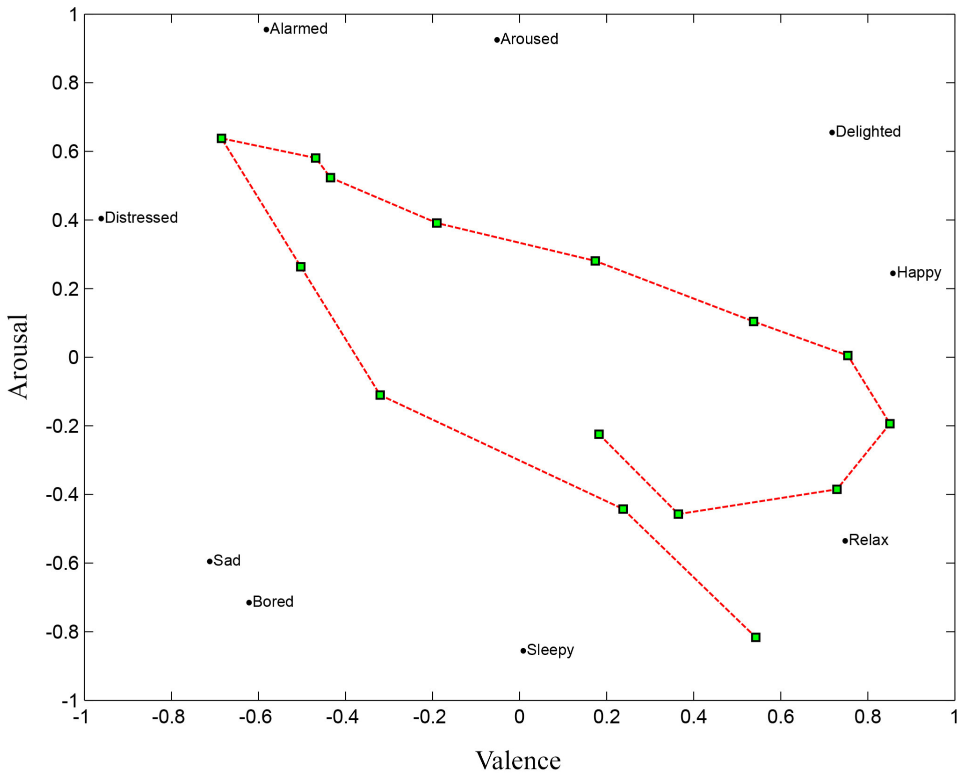

Figure 5.6: Estimated valence arousal coordinate transition throughout the whole day. The transition made from morning to evening is anticlockwise

hands' position is 50%. The 11th mood represents the agent with 30% distressed and 40% of alarmed with hands' position of 83%. The 15th mood represents the agent with 22% of sleepy and 50% of relaxed with hand position of 10% down.

5.4.1 Behavior network for choosing agent behavior

Besides transmitting the remote user's mood, the agent also aims to generate other affective behaviors. Since imitation is not the only behavior of the agent, a control mechanism is required to decide on the agent's behavior. In this respect, a model is needed to define the relationship between the user's and partner's mood and the synthetic agent's behavior. In a behavior network, every node has its intrinsic attribute of precondition, add list, delete list, activation and executable code, which determines the previous and the next link that will be activated. Preconditions are sets of condition that must be correct to activate the node. Add list is the condition that will be or remain true when the node is activated. The delete list is the condition that will be or remain false when the node is activated. The activation level will determine which behavior is executed. Then there is an executable code that will be activated when the precondition for the node is fulfilled.

In this behavior network, the behavior node, environment and goals are connected by links. There are two types of link, an internal and an external link. The external link consists of sensors or the environment and the internal links can

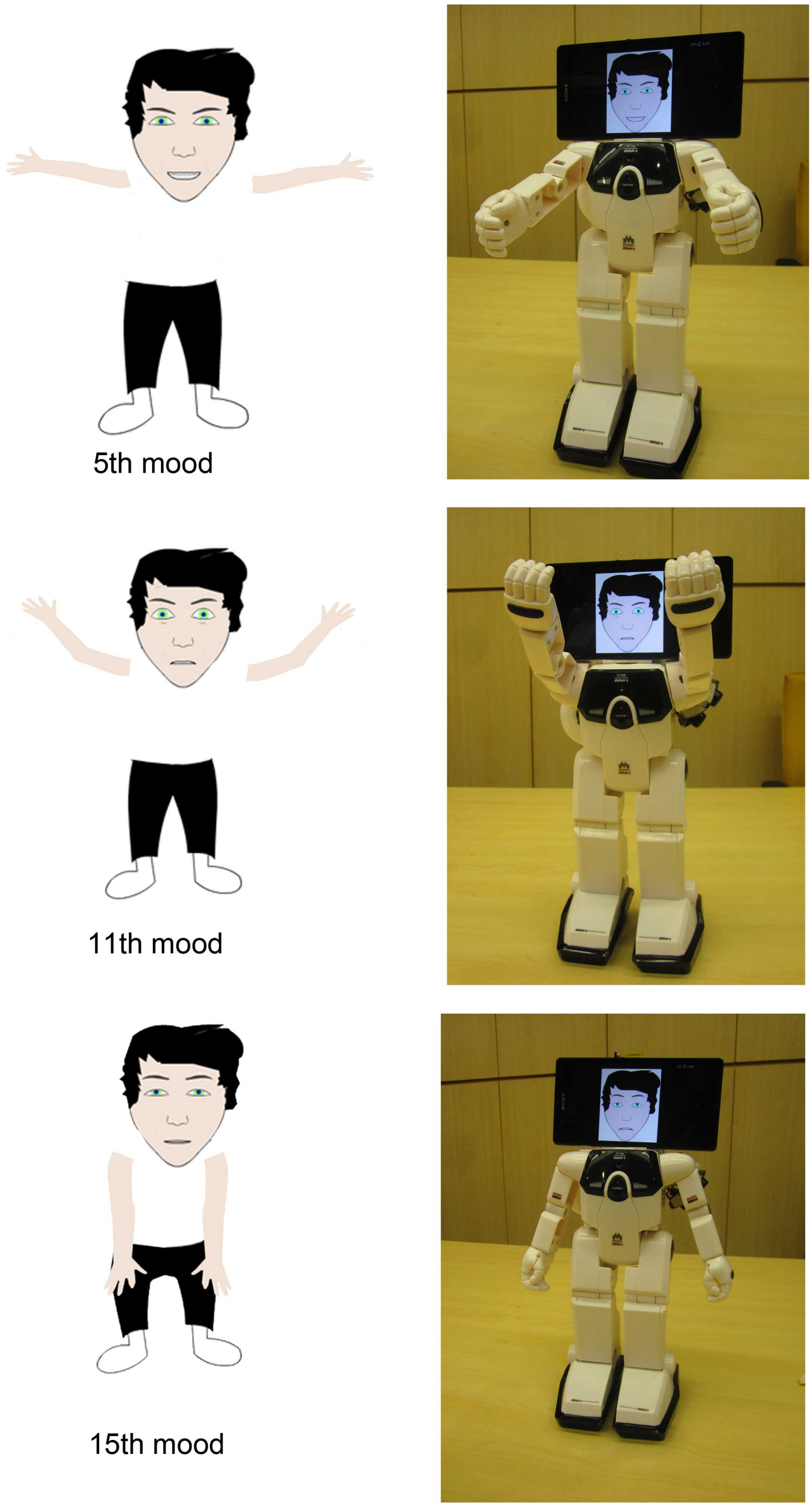

Figure 5.7: Visualization of the agent behavior through a simulator

be divided into three links which are the predecessor, successor and conflictor links. The successor link is activated, when the add list of the previous node is a member of the precondition of the following nodes. The predecessor link exists when the successor link is activated but in the opposite direction. The conflictor link is activated when the precondition of the previous node, and is a member of the delete list of the following nodes. The activation condition of each link from the i^{th} behavioral entity to the j^{th} behavioral entity can be defined as follows (p is the current condition) [221].

$$Predecessor : (p = false) \cap (p \in precondition\ of\ B_i) \cap (p \in addlist\ of\ B_j)$$

$$Successor : (p = false) \cap (p \in add\, list\, of\, B_i) and (B_i\, is\, executable) and (p\ \in precondition\, of\, B_j)$$

$$Conflictor : (p = true) \cap (p \in precondition\ of\ B_i) \cap (p \in delete\ list\ of\ B_j)$$

Suppose the agent m is comprised a set of precondition list (x_p), add list (x_a), delete list (x_d), and activation level (α). Then node $B_j(x_{pj}, x_{aj}, x_{dj}, \alpha_j)$ is a successor of node $B_i(x_{pi}, x_{ai}, x_{di}, \alpha_i)$ if the member of precondition list of node j is add list of node i, e.g. $(x_{ai} \cap x_{pj})$. And then node i will be conflictor of node j if the member of delete list of node i is member of precondition list of node j, e.g. $(x_{ai} \cap x_{pj})$.

The links between the nodes serve to spread the activation value (α), where the activation level will be spread forward from the executable node through the successor link, and it will spread backward from non-executable node via the predecessor link. The activation level of each node in each time step is the sum of the previous activation level with the change of activation level

($\alpha_{(t+1)} = \alpha_t + \Delta\alpha$). The change of the activation level is obtained from three sources, forward spreading, backward spreading and internal spreading. In the forward spreading, activation level (α) is updated based on the environmental sensors that are preconditions of a behavior node as shown in equation 5.9

$$\Delta\alpha_f = \sum_{i=1}^{n} f(\alpha_s) \tag{5.9}$$

$$f(\alpha_s) = \begin{cases} \Phi\alpha_{si} & if(S_i = true, S_i \in precondition\ of\ B_i \\ 0 & if \quad S_i \notin precondition\ of\ B_i \end{cases} \tag{5.10}$$

where n is the sensor number, and α_{si} is the activation level of the sensor i and Φ is the amount of activation energy injected by the sensor. In the backward spreading, activation level α is updated based on the goals of the agent that are add list of one of the behavior node as shown in equation5.11

$$\Delta\alpha_b = \sum_{i=1}^{n} f(\alpha_G) \tag{5.11}$$

$$f(\alpha_g) = \begin{cases} \gamma\alpha_{G_i} & if(B_i = true, G_i \in \ precondition\ of B_i \\ 0 & if \quad G_i \notin precondition\ of\ B_i \end{cases} \tag{5.12}$$

where n is the goal number, and α_g is the activation level of the goal and γ is the amount of activation energy injected by the goals. In the internal spreading, activation level α is updated through the internal link between each behavior node by the predecessor, successor or conflictor links as shown in equation 5.13

$$\Delta\alpha_n = \sum_{i=1}^{n} f(\alpha_{b_i}) \tag{5.13}$$

$$f(\alpha_{B_i}) = \begin{cases} \alpha_{B_i} & if (Predecessorlink from B_i) \\ \Phi/\gamma\alpha_{Bi} \quad if & (successor\ link\ from B_i) \\ -\delta/\gamma\alpha_{Bi} \quad if & (conflictor\ link\ from B_i) \\ 0 & otherwise \end{cases} \tag{5.14}$$

where n is the behavior number, and α_B is the activation level of the behavior node and γ is the amount of activation energy taken away by the node following the conflictor link [234]

To summarize, the activation level α in each time step can be calculated as shown in equation 5.15

$$\alpha_{t+1} = \alpha_t + \Delta\alpha_f + \Delta\alpha_b + \Delta\alpha_n \tag{5.15}$$

Finally, the network has to evaluate the following conditions to determine which node is supposed to be executed (*i*) the node has to be executable, (*ii*) Its level of activation has to surpass a certain threshold θ and (*iii*) It must have a higher activation level than all other nodes which fulfill conditions (*i*) and (*ii*) [235].

In the proposed behavior network, The environment and sensing part of the behavior network comes from the Bayesian Network output, which consists of the user and partner's mood and local time. There are three goals in this behavior network, imitation, feedback and special time. The imitation goal triggers the character to imitate his/her partners's mood. The feedback goal intends to give feedback for the user's mood. The special time goal greets the user about the time change. the special time goal is triggered when there is a change in the time period such as morning afternoon and evening. The feedback goal will be triggered when there is a prominent user's mood that reach a certain threshold, otherwise the imitation goal will be activated. Based on the proposed link in the behavior network, we developed the activation level model using the forward and backward spreading as there are no internal links between the behavior node. In the feedback mode, the personality of the partner is considered and represented by the animation speed. The behavior network will determine the animation of the character behavior, and the animation speed of the character depends on the personality of the partner the more extrovert the partner, the faster the animation of the character. The designed behavior network is shown in Figure 5.8

To demonstrate how the agent's goals are automatically selected based on the activation level, an experiment with a pair of partners is performed. Figure 5.9 shows the activation level of the nodes in the behavior network on each hour of the experiment day. In this graph, the behavior with the highest activation level will be expressed on the character.

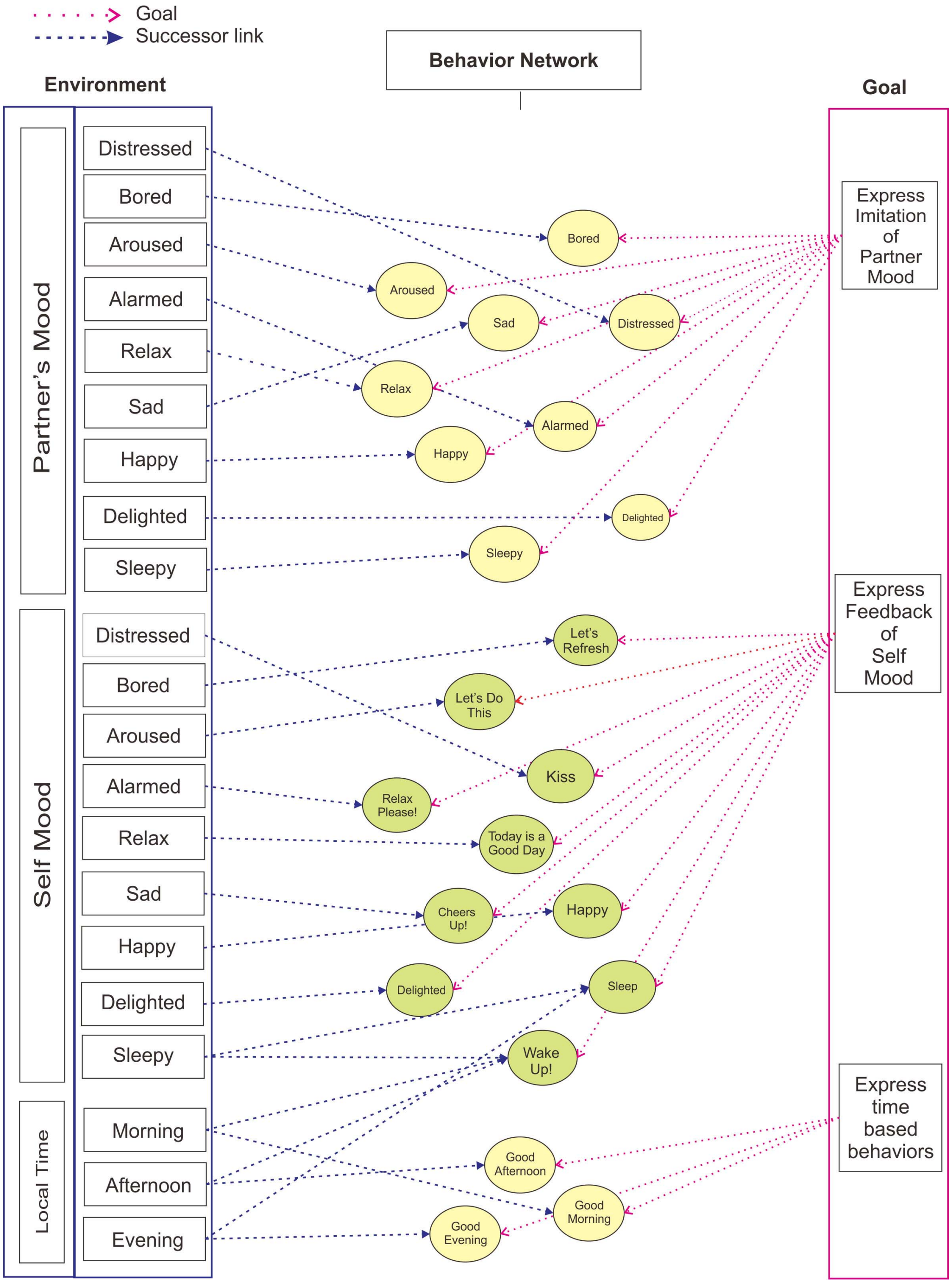

Figure 5.8: A designed behavior network

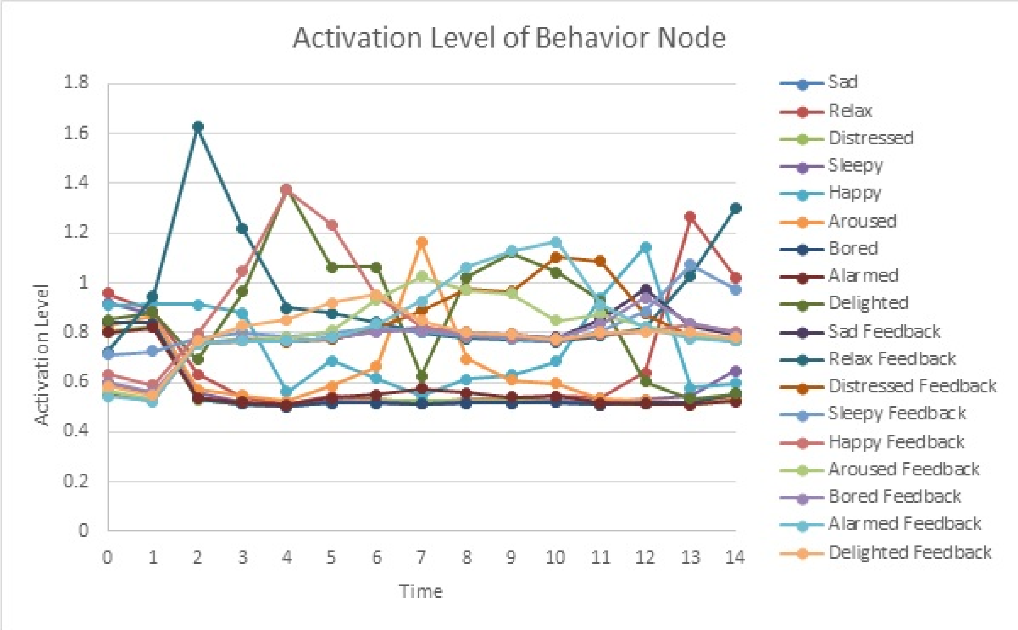

Figure 5.9: Activation level of each behavior node captured once per hour

Five sets of the mood data from the user and its partner with the respective animated agent's behavior is shown in Figure 5.10. The proposed AI is applied in a smartphone Android app and the prototype screenshot is shown in Figure 5.11.

5.5 Evaluation of the intelligent affective telepresence system

In order to evaluate the system, 10 active smartphone users ($N = 10$), including 5 females and 5 males, who aged between 21 to 33, ($Mean = 25.8, SD = 3.82$), were randomly selected from National University of Singapore staff and students. None of the participants had previous experience of interacting with similar technologies such as empathetic virtual agents or emotional robots. The

(a) (b) (c) (d) (e)

Figure 5.10: Visualization of the auto-generated animated agent behaviors for different scenarios.
(a) Special time: Morning; User Mood 22.02% Relax; Partner Mood 20.84% Relax
(b)Not a Special time: Morning; User Mood 44.39% Relax; Partner Mood 16.77% Happy
(c)Not a Special time: Morning; User Mood 64.61% Sad; Partner Mood 22.37% Happy
(d)Not a Special time: Morning; User Mood 46.71% Relax; Partner Mood 46.40% Delighted
(e)Not a Special time: Morning; User Mood 54.99% Relax; Partner Mood 52.16% Sleepy

evaluation was performed in two stages. In the first stage the PME module was evaluated and in the second stage, the fitness of the virtual companion behaviors was tested.

The PME was tested by comparing 120 samples of mood data inferred from the proposed PME model against the self-reported user moods. Each user has logged the smartphone usage and context data such as time, location, running apps, call logs, etc. in relation to their self-perceived mood. The self-perceived user mood state was compared against the result of the proposed model. The Mann-Whitney U test [236] was used to evaluate whether or not there is any significance difference in the valence-arousal space between the self perceived and

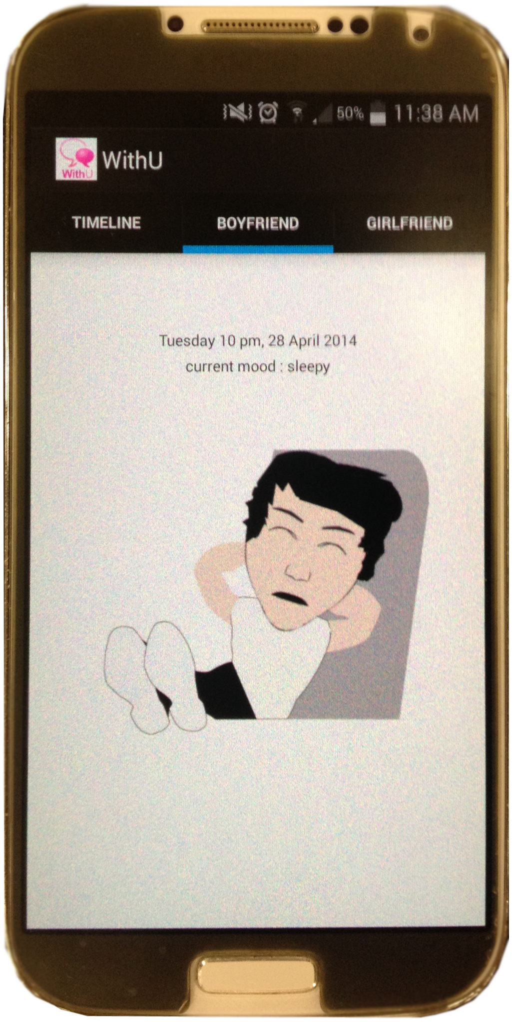

Figure 5.11: Demo of the proposed app on smartphone

the automatically inferred result. Figure 5.12 shows one sample of the perceived mood compared to the estimated mood state. The p value for two tailed are 0.64 for the valence space, and 0.73 for the arousal space. Both p values are higher than 5%. Therefore it could be concluded that there is no significance difference in the proposed model and user self perceived affective state. This suggests the success of the PME model in the estimation of the mood state of the user.

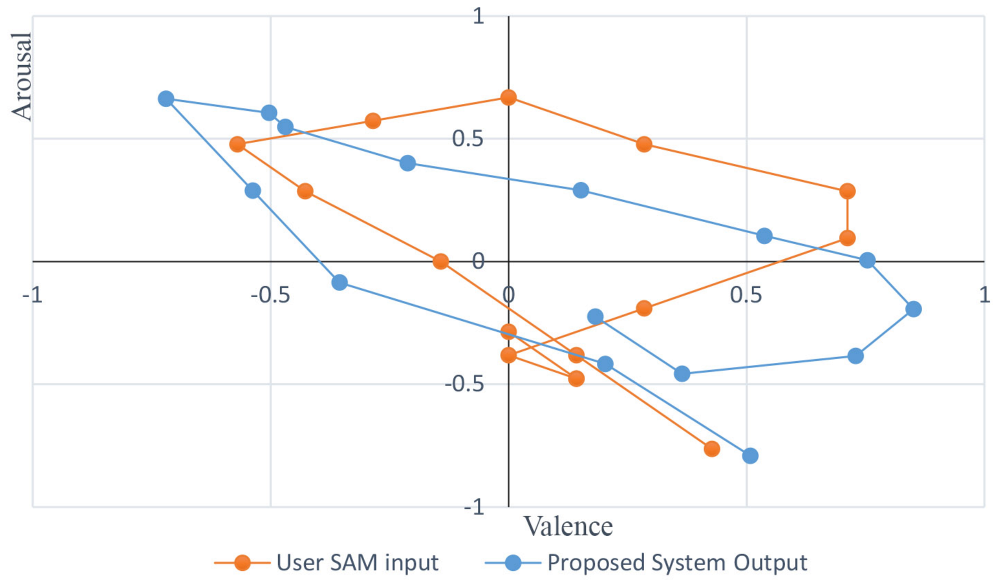

Figure 5.12: A comparison of the estimated mood state versus user self perceived mood

In the second experiment, the goal was to confirm that the interactive companion could produce appropriate behaviors. The fitness of the virtual companion behaviors points to the correspondence of the auto-generated agent's behavior from the point of view of the users.

Since the suitability of the behavior is a subjective issue and cannot be measured quantitatively, we adopted the method proposed by [221] to assess the model. In this method, 12 people participated. The participants were given 10 different combinations of the user mood (themselves), artificial agent's mood, smartphone state, user activity state, and time of the day (special time or not). For each scenario of the mentioned combinations, they observed 5 randomly generated behavior by the animated agent followed by 5 behavior generated by the proposed behavior network. They were asked to rate the appropriateness of the behavior from 1 (strongly inappropriate) to 5 (strongly appropriate). The mean fitness scores of each participant were calculated as shown in Table 5.5. The result was analyzed by Wilcoxon signed-rank test with the fitness scores. As a result, the p value was obtained as $0.002 < 0.5\%$ which confirms that the proposed model succeeded in generating suitable behavior compared to the random generated behaviors. More details of the analysis is shown in Tables 5.5 and 5.5

Participant	pa1	pa2	pa3	pa4	pa5	pa6	pa7	pa8	pa9	pa10	pa11	pa12
Random	2.75	2.25	1.87	2.5	3.125	2.25	2.75	1.62	2.5	2.12	2.5	3.12
Behavior Net.	4	4.25	3.37	3.25	3.25	3.87	3.62	3.62	4	3.12	3	3.37

Table 5.6: Mean fitness ranks for fitness of agent's behavior in two scenarios of random and behavior network generated behavior.

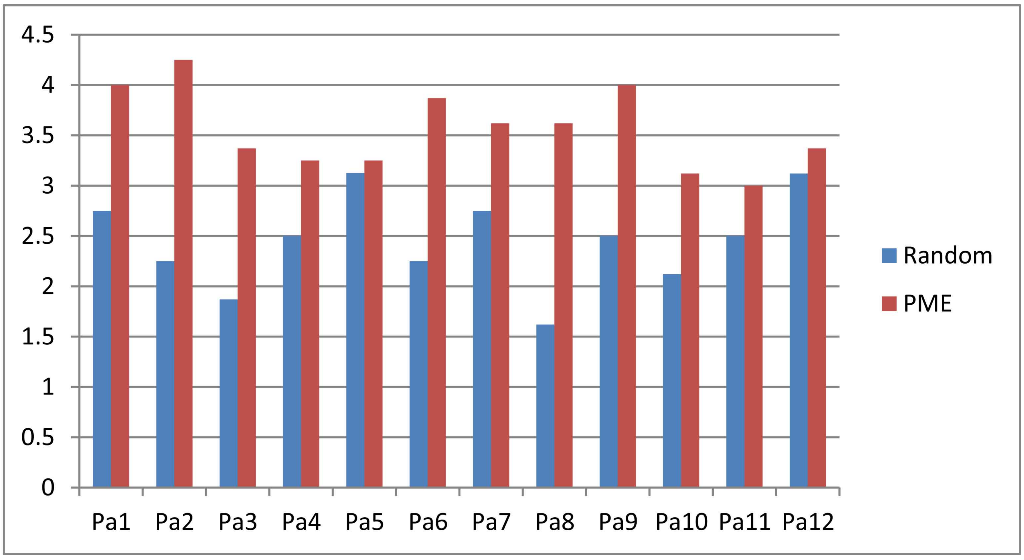

Figure 5.13: The histogram of the estimated mood state versus user self perceived mood

	N	Mean	Std.	Minimum	Maximum
Random	12	2.45	0.46	1.62	3.13
PME	12	3.56	0.40	3.00	4.25

Table 5.7: Descriptive statistics on perception towards random vs PME generated behaviors .

	PME_Random
Z	-3.062 a
Asymp. Sig. (2-tailed)	**0.002**

Table 5.8: Wicoxon signed rank test results comparing “PME” output against “Random Generated”

5.6 Summary and Conclusion

The main aim of this chapter was to support phatic communication between remote, intimate partners using smartphone high level sensing. The **phatic communication**, which opposes to **content communication**, is the type of interaction which has a social rather than informative function. They can be considered as communication that is low in information or data but is nevertheless high in significance and/or meaning [21]. The main objective of phatic technologies is satisfying the need to feel connected [21]. In this respect, an AI based model is proposed to estimate the probabilistic mood state of each user and visualize it on the other side through an artificial agent. This helps to maximize ongoing connectedness with the intimate partner. This kind of probabilistic mood estimation should not necessarily communicate the exact, accurate information, since the focus is not the content. However, it should maximize the connectedness. The approach of automatic inference from the smartphone can maximize the connectedness because it supports agent behavior generation, even when both users are not simultaneously available. The result of this chapter could be applied to address the need of ongoing connectedness in LDR, which was pointed as “research problem 3” in section 1.2.

The system is designed for active smartphone users. The PME module supports mood inference through the smartphone, considering the uncertain, insufficient, and dynamically changing available data. To visualize natural mood transitions in a natural way as well as the association of the agent’s expressive behaviors to the remote partner, the personality type of the remote user influences the regenerated mood. The association of the personality to the agent has two benefits. Firstly, it makes the agent more believable and natural [237]. Secondly, the agent will have similarity (attribution) to the person that it represents. The system also provides feedback to the local user’s affective state on behalf of the remote partner. Since the model should handle multiple goals a behavior network is designed to handle the goal selection.

The proposed model facilitates telepresence with the remote, intimate partner by transmitting the mood and reacting to the mood state. Mood is a type of affective state similar to emotion, but it lasts longer than emotions and is a reaction to a sequence of events. Besides, mood is a private concept, as opposed to emotion that is noticeable by others [220]. Therefore, mood due to its private nature, can reflect the underlying feeling of a person and its sharing could support intimate interaction. This study has taken the first step in smartphone-based agent control for intimate telepresence. It also introduces a novel approach for mood sensing without putting the burden of mood logging and system training on the users. Moreover, it is the first attempt in intimate telepresence that facilitate communication without the need of simultaneous presence of both partners. This is especially important in LDR communications that time and context differences are barriers in interactions.

The proposed AI model is applied on the smartphone and the success of the system is evaluated. In terms of mood inference the model was able to recognize the user's mood state with insignificant difference from the self perceived mood. In relation to the feedback to the user's mood, the results showed the model could generate relatively appropriate feedback.

The study has introduced a novel application of pre-existing methods such as DBN and Behavior Networks for the purpose of intimate telepresence. Also, the designed DBN for affective state recognition and the designed Behavior Network for activity selection are the other novelties of this study.

It should be noted that the study has some limitations. First, it aims to estimate the probabilistic mood state based on the data sensed by smartphone sensors and not all the mood change triggering factors. The model is not currently perceptive to the common social and environmental factors that might influence the mood state. (e.g. content of conversation, weather, health state, traffic). It is acknowledged that external and unpredictable factors cannot be considered with this approach. The system therefore cannot be expressed as an information exchange source, however, it still fulfills its objective of phatic communication. Second, since the affective state is a subjective concept due to its nature, accuracy is not measurable but can be estimated. Further research is needed to extend this model to include more contextual and internal data to assess the user's mood. Smartphone-based activity detection techniques could be also integrated with this model to teleport richer sets of behaviors. Moreover, the detected mood state depends on the defined rules for the DBN model. The current DBN rules in PME modules, that define relations between users' interaction with the smartphone and their mood, are based on the surveys with smartphone users and commonsense . More research by social scientists and psychologist in this area could help to define more generalizable and reliable rules for PME module of the system. Besides, perceiving the affective expressions of the agent varies from person to person due to their cultural backgrounds, emotional intelligence and social skills. Customized affective expressions for different cultural backgrounds can address this issue, which is the focus of cultural robotic researchers.

Chapter 6

Haptic Telepresence

6.1 Third level of modeling: Telepresence Agents for mediating intimacy through haptic communication of kisses

Motivated by the lessons learnt from the previous study, to get more benefits from the physicalness of physical avatars, a study on haptic feedback from the robot was performed. Mediated physical intimacy was explored by the study about emulating kisses. Until now, within HCI literature, there is very little research based around teleporting kisses.

For instance, *Intimate mobiles* [97] attempts to provide realistic telepresence using a mobile phone. In which grasping, kissing and whispering are imitated using a hand loop and human skin heat, hydrated sponge, and airjet respectively. However, due to the human likeness and literal emulation of the kiss, the user study reflected creepiness and unpleasantness of the system. The opposite design perspective is *kiss communicator* [98] developed by IDEO, which investigates the sensual exchanges between individuals in an ambiguous way. It transmits kiss poetically by squeezing and blowing the interface. The issue with this approach is that, although such an interface conveys a sensual feeling, since it is very implicit, it might not make up for the absence of actual kisses. It also does not stimulate the tactile sense the way that is expected from an actual kiss. *CheekTouch* [99, 100] stimulates tactile feedback via mobile phone. It senses finger touch pattern and sends haptic feedback on the remote person's cheek using vibration. In this design approach, since a mobile phone is a many−to−many device that is used for communication with everyone, not exclusively with specific person, it opposes the private nature of intimacy [86]. *Hkiss* [101] aims to send a kiss from a 3D virtual avatar to the physical world through haptic actuation, though the haptic feedback system is very rudimentary both from the design and the technical perspective. Therefore, although very few previous works have also focused on mediating kisses, they are very limited in terms of design exploration, anthropomorphism, and correspondence between the perceived kiss message and the original kiss generated by a remote user. To provide a more natural and bidirectional intimate kiss we have conducted an iterative design practice to develop a telepresence kiss medium for long distance relationships.

6.1.1 Importance of affective touches in intimacy

Affective touch, like kisses, hugs or close physical proximity, as stated in[238] "Is critical for physical and mental well-being". They play a significant role in expressing an important part of intimacy that is better expressed through sensory evocations rather than linguistics. For romantic LDRs, distance has led to the absence of the physical being of the partner in one's daily life, making them lose the opportunity of haptic experiences from these affective touches. This is a serious problem, in general, as it strongly affects the intimacy and connectedness of the romantic relationship. Therefore, mediating affective touches through technology is a potential solution to address this problem by providing a haptic communication channel to trigger the *presence-in-absence* and exchange these, emotion and affection laden messages. This will support remote communication between LDRs at a more affective and experiential level.

Kissing can express sentiments of intimacy as well as love, passion, affection, respect, greeting, friendship, and good luck. Kissing is one of the most important modes of human interpersonal communication [239]. Despite the availability of haptic communication devices, not much attention has been given to the use of the kiss as a mode of remote social interaction. Considering this missing dimension of representing a kiss using current remote communication technologies, we aim to design a device to facilitate the exchange of emotional content between people who are physically separated. We proposed to address this vacuum by designing a system called *Kissenger* that consists of two paired devices that can send and receive kisses simultaneously, giving people a new dimension to express themselves. Our intention was not to replace, but rather augment existing remote communication technologies with Kissenger. We approached this design problem carefully through iterative prototyping and evaluations, given the intimate nature of the interaction.

The following sections, describe our design methodology, an iterative development process where each iteration is based on feedback from a user evaluation. Afterward, the field study with ten couples who used Kissenger in actual everyday situations over a period of time is described. It provided a better understanding of the influence of Kissenger in mediating intimacy in LDRs. Then Discussion and design lessons are elaborated. Finally, our learning from this study and design lessons are summarized.

6.1.2 Creating Kissenger

In designing for new contexts and expressions, innovative methods are needed to involve users and development teams. It is argued that user involvement through structured formative evaluation design can bridge the conceptual and procedural gaps between system design and system evaluation [240]. We used the method of Experience Prototyping [241] that "is founded upon the observation of our own practices that shows that we can be more sensitive, can design better experiences for people, and can be more convincing about the value of our design decisions, by intentionally adopting such an approach."

We used an iterative process where at each stage, we analyzed the design requirements using feedback from the earlier stage, executed a new prototype and subsequently evaluated them through user studies [242]. The method of Experience Prototyping details that during the initial exploration and evaluation stages, especially in the understanding stage, there is great value in low fidelity prototypes.

6.1.3 Defining interaction for Kissenger

Traditionally, couples that were involved in LDRs relied on text and letters to convey emotions and intimacy. Subsequently, the telephone allowed for communication through audio. Recently, the visual dimension was added through technologies such as video chat. Currently, multimodal text, audio, and video interfaces are commonly used between family members, partners, and friends who are co-located. During the initial stages of the project, we asked couples specifically about the missing dimension of current technology related to kissing and they mentioned that current methods that they use are missing the tangible or visible form of kissing. We understood that couples ideally prefer to kiss each other naturally, but current lifestyles require many instances when couples have to resort to remote communication methods. Considering the above-mentioned issues, we started designing a device that can bridge this gap through an iterative development method.

6.1.4 Iterative development of the Kissenger

We developed Kissenger in four major iterations, that progressed from evaluating the idea, towards defining the physical shape of the device, then to the characteristics of a kiss and finally to improve the usability for the field study.

6.1.4.1 The first version of the Kissenger

At this stage we focuse on evaluating the feasibility of our idea.

Design The lips play one of the most important roles in the kiss process [243] and we decided to focus our first prototype on them. A series of exploratory form factors were drawn to help us visualize the possible interfaces. Figure 6.1 shows some of our initial designs that were suggested during a focus group session. For the focus group five couples with the previous experience of LDR joined the workshop. They were recruited from students in our university by word of mouth. Their ages ranged from 21 to 30, (Mean=25.2, SD=3.32), with the minimum 2 months up to one year experience of LDR. They were requested to generate design ideas on the appearance of the Kissenger. At this stage, we looked into various styles of kissing. In addition to kissing between partners, we explored the possibility of parents using this device with their children, and included other representations such as lollipops.

One key issue was that the use of the device should be comfortable, and would not distract or obstruct the natural interaction of the kiss. We decided to develop a lifelike lip and surround it with a minimalist shape and focus just on the structure. Figure 6.2 (left) shows the 3D depiction of the proposed device. Considering the size of the internal circuitry, acceptability and believability by a user, we decided to choose a lip size that is similar to that of a human being for this version. We evaluated our form factor, without the internal circuitry, using the prototype shown in Figure 6.2 (right).

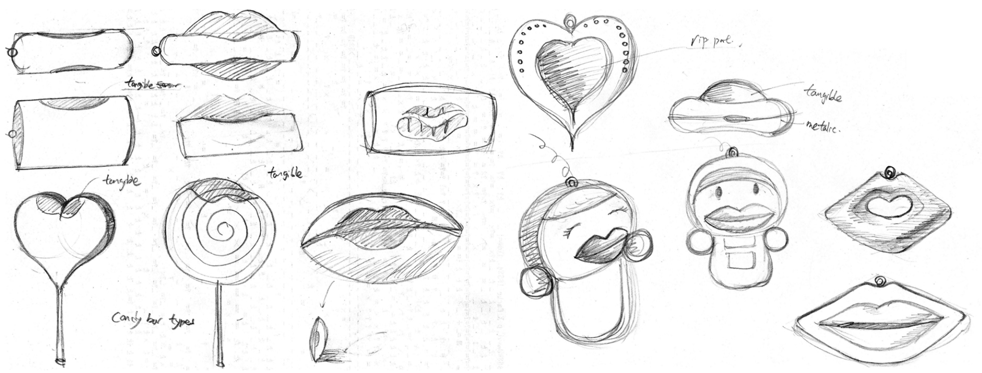

Figure 6.1: Preliminary design sketches for our first version of the Kissenger.

Evaluation of the first version of Kissenger An assessment of the concept and its implementation was conducted in a focused group with 16 people studying or working in our university. They were all likely to use a kiss messenger by expressing their interest in the idea of mediating kiss. They were recruited through the mailing list and advertisements around the campus. The ages ranged from 20 to 38 with the Mean= 28.18 and SD=5.03

The process was short and flexible and consisted of a brief introduction to the concept, the vision and goals of the project, followed by allowing the participants to interact with the system, while continuously eliciting impressions of the overall experience and any feedback they may have by verbal conversations. We wanted to know whether they could envision using a system like this and what features were important for them to adopt this device into their everyday lives.

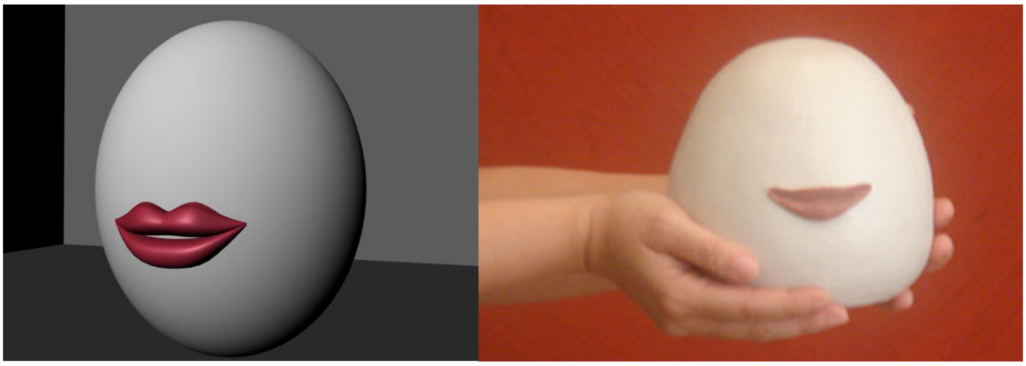

Figure 6.2: Proposed shape (left) and the user evaluation prototype (right) for the first version of Kissenger.

Most users liked the idea of a device that could transmit a kiss to their loved one, and gave us many comments for the prototype. The most important feedback received was that the prototype did not have any personality. The egg shape of the device along with the pair of lips elicited some users to call it "creepy". Other feedback included the large size of the device that required both hands for comfortable usage and that the affordance of the device were not clear with its current form. They wanted the ability to carry the prototype with them every day and asked for a device comparable to the size of a mobile phone.

6.1.4.2 The second version of the Kissenger

At this stage we focused on defining the physical shape of Kissenger.

Design Armed with the feedback from our first prototype, a number of design revisions were made, the most important being the shape surrounding the lips. We needed to make it more aesthetically welcoming. The field of robotics has a theory of the uncanny valley [96] where expectations evoked by a robot fall short of actual look and feel, producing an interaction that can feel strangely uncomfortable to humans. Many researchers have tried to target a very human-like appearance, most notably "Android" by Ishiguro et al. [244]. We believed that for the purpose and type of task that our device needed to perform [245, 246], we needed to target a cute design, similar to a stuffed toy. It could minimize the risk of uncanny feeling which might be perceived by realistic design.

The design of the device is based on an animal where the combination of a caricatured and zoomorphic representation is useful and effective to accomplish our goals, rather than using complex, realistic representations [247]. Figure 6.3 shows some of the initial forms we sketched for the head of the second prototype. In this design, we also tried to reduce the uncanny nature of the prototype by making cuter shapes as shown in the subsequent forms we sketched. Feedback from the researchers in our laboratory and external designers helped us choose the final design shown in Figure 6.4 (left).

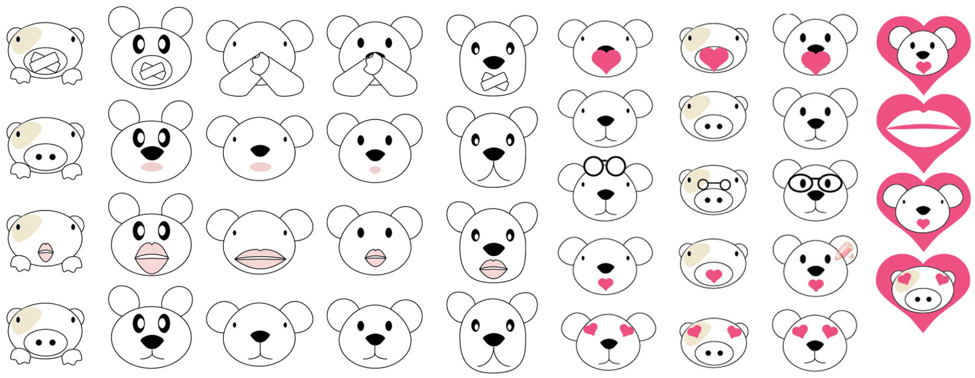

Figure 6.3: Some possible forms for our second prototype of the Kissenger.

Evaluation of the second version of the Kissenger We used the developed prototype as shown in Figure 6.4 (right), for the user evaluation. The second version was evaluated in a focused group within our laboratory by researchers not involved in the implementation of the prototype. A total of 14 participants aged from 19 to 42, (Mean=27.42, SD=5.97) consisting of 7 males and 7 females attended in the study. The focused group took around two hours to evaluate the prototype. They tried the prototype and provided suggestions for improving it. The suggestions were transcribed and analyzed. The important and repeating feedbacks reflected the appearance and the quality of interaction. The feedbacks pointing to the appearance were mainly satisfying whereas interaction feedbacks were rather negative. Positive feedback was received for the shape and size of the prototype. The majority of the negative comments were towards the quality of the lips. Unlike the first prototype, which had a lifelike shape and touch sensation, in this version the material was rather hard and was covered with paint. Our next iteration we would need to take these issues into account.

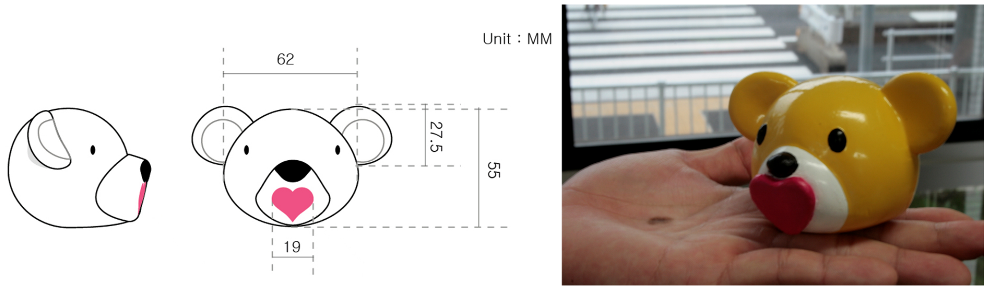

Figure 6.4: Final design for the second version of the Kissenger.

6.1.4.3 The third version of Kissenger

At this stage we focused on the character of a kiss by defining the interactions of Kissenger.

Design After using the previous two versions to decide on the outer structure of the device, we decided to focus on the actuation and interaction mechanism of the device. Based on the haptic and intimate experience of a kiss, each device would be paired with another device. The design would incorporate a real-time bidirectional communication, in which each user can send and receive signals. We decided to adopt an asynchronous design that requires no synchronization prior to transmission, allowing users to send and receive at the same time. Based on the feedback from the second prototype, we first needed to choose a material and shape for the lip. We tried different materials available commercially. Room temperature vulcanizing (RTV) silicone rubber type of 560 was chosen for this prototype based on its texture and colour that closely resembles a human lip. For the lips, we designed a shape that is cuter in nature, but provided the movement of a human lip as shown in Figure 6.5 (left). The device we developed for the third prototype is shown in Figure 6.5 (right).

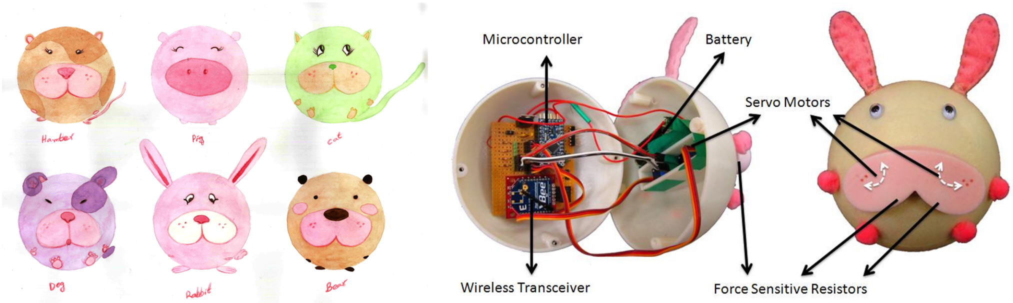

Figure 6.5: Preliminary design drawings for Kissenger (left) and the prototype device (right).

The interaction mechanism for Kissenger was devised with a number of features that we believe will make kiss communication between two users more meaningful as shown in Figure 6.7. The system consists of the following key features:

1. Output kiss actuation: The kiss sensation is produced through movement of servomotors that distend the surface of the lip. The shape and size of the lip covers and hides the opening of the device and the inner electronics that go into the sensing, control and actuation of the device. This makes the user more amicable to the device and helps evoke emotional responses and feelings for kiss communication.

2. Input kiss sensing: The front of the lip has force sensitive resistors placed just below the outer surface, unbeknownst to the user. It can sense varying levels of soft touches. The force variation is sensed, digitized, and

transmitted wirelessly to the receiver device. The sensors are mapped on a one-to-one basis to the actuators on the receiver device. This design simplifies the interface and enables users to form a correct and semantically meaningful mental representation of the system.

3. Control and wireless: Each device is equipped with a lip connected to an embedded circuit that orchestrates the entire system. The circuit contains an Arduino Pro Mini that controls the sensors and actuators. It can communicate wirelessly with another device. Data from the pressure sensors is read continuously until a change is detected. If there was a substantial change, the resulting increase is transmitted wirelessly to a receiver circuit that then actuates a servo motor array to produce vibration of the lips. The schematic diagram of the internal circuits is shown in (Figure 6.6).

Evaluation of the third version of Kissenger In order to evaluate the effectiveness of our prototype, we compared it against a video chat application, Skype, in a controlled experiment. We recruited seven couples to participate in this evaluation. None of them had previously used the devices. The ages of the fourteen participants were in the range from 22 to 30 years and had known their partner for nine months or more. They have had an experience where a part of the relationship was long distance that involved some form of distance communication. The experiment took place in our laboratory meeting room divided into two partitions.

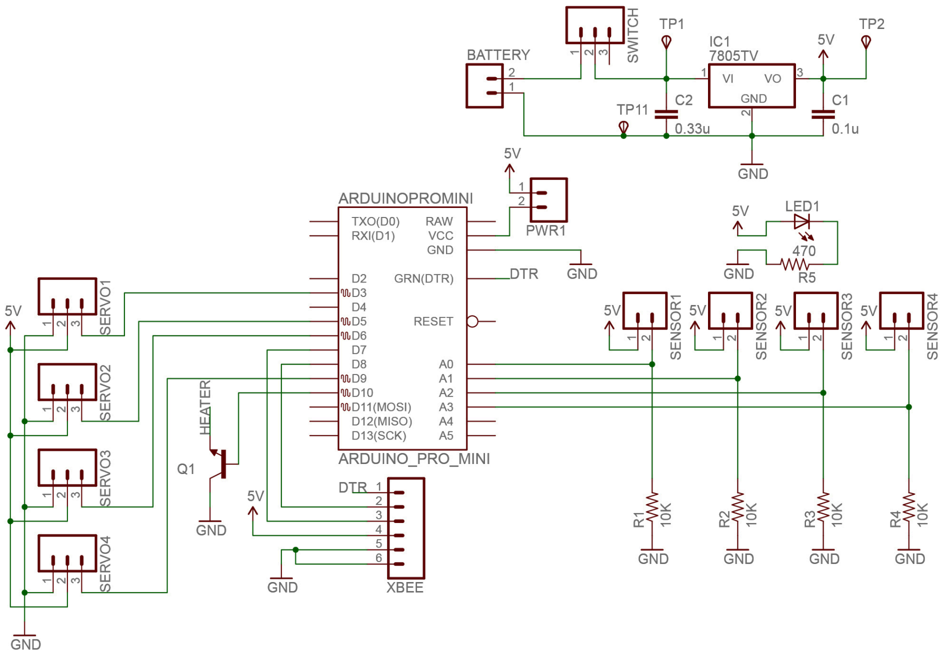

Figure 6.6: Schematic diagram of the Kissenger internal circuits.

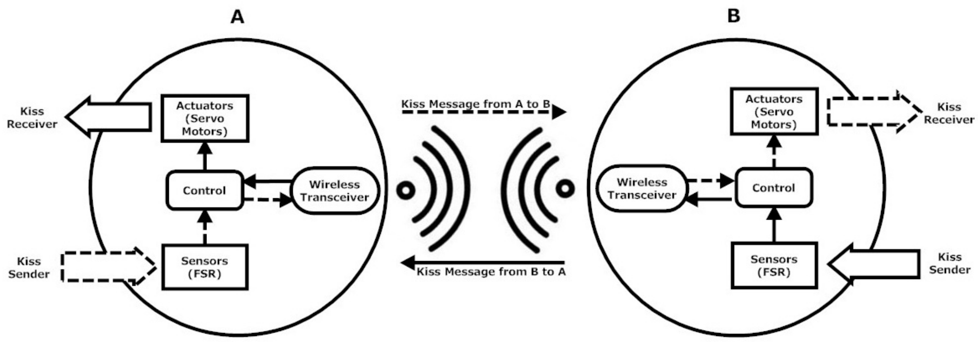

Figure 6.7: Block diagram for the third prototype of the Kissenger. Dashed arrows show the direction of the sender's interaction from A to B and the solid arrows show the interaction from the opposite direction.

The experiment took almost twenty minutes per couple of participants to complete. Since our goal was to evaluate Kissenger in the context of intimate and affective communication, we asked participating couples to choose a topic and mention phrases that in their normal conversation is usually followed by kiss (a greeting for example). They would have to complete two scenarios including, sending the kiss through the emoticons in the video chat itself and through Kissenger. Initially, each user was explained the scenarios, how to use the device and were given some time to familiarize themselves with the device before the start of the evaluation itself. After each scenario, participants completed a 7 point likert scale questionnaire about the setup used. After trying both scenarios, in a counterbalanced order, participants completed a summary questionnaire asking for their demographic information and any feedback they might have.

The objective of our experiment was twofold. Firstly, we wanted to test whether using a mediated kiss device such as Kissenger enhances the affectivity of communication compared to common affect expression methods in telecommunications such as emoticons for text or audio-visual affect expression. Secondly, we wanted to inspect the role that Kissenger has in fostering the sense of co-presence; when a remote user is kissed by the partner using the device, to what extent is the illusion of being together conveyed.

The results show similar experiences for both scenarios ($t(13) < 1.99$, n.s.)

with the exception of two affectivity questions, "Does communication through this interface create an intimate experience?" and "Was the received kiss similar to a natural kiss?" for which a paired two-tailed t-test revealed that Kissenger received a significantly higher score ($t(13) = 4.59, p < 0.01$) and ($t(13) = 2.24, p < 0.05$) respectively (see table 6.1.4.3). These results are consistent with our design goals.

Improvements	t	df	Sig. (2 tailed)	Mean (Kissenger)	Mean (no Kissenger)
Intimacy	4.59	13	0.0005	2.8	2
Naturalness	2.24	13	0.043	5.30	3.15

Table 6.1: Paired two-tailed t-test results for comparing the perceived naturalness and intimacy with and without using Kissenger

Users explained that the physical interaction with the device was analogous to the interaction one might have with their partner. These findings suggest that the physical interaction with Kissenger increases the emotional engagement with the device and the partner it communicates with.

Kissenger uses wireless technology to transmit the digital equivalent of a kiss. There are some important conditions necessary to appreciate the experience of this prototype: an intimate relationship, two distant people, and a method used to synchronize the time of the kiss such as a phone call or video chat.

The two prototypes that were made in the third iteration for the user study were not as robust and reliable as we had imagined. Towards the end of the evaluation, the connection between one servo motor and the lip slipped out requiring researcher intervention. The placement of the heavier components of the circuit was not optimal, making the Kissenger roll towards its center of mass near its mouth whenever it was placed on a flat surface. We created holders for these devices for the evaluation as a workaround. Both these issues will be solved in the next revision with better industrial design.

6.1.4.4 The fourth version of the Kissenger

At this stage we improved the usability of Kissenger in preparation for a long term study.

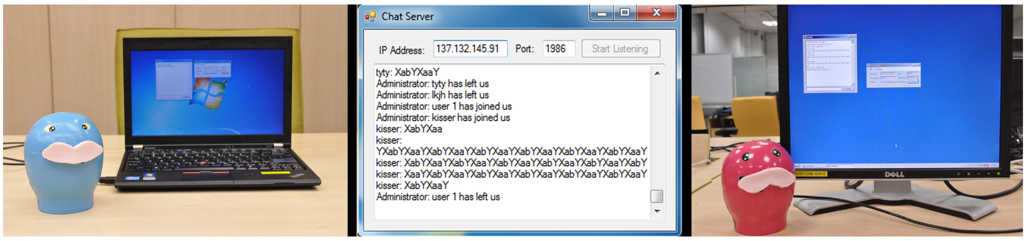

Figure 6.8: Prototypes connected to the PC running the client application (left and right) and the server application developed for connecting the devices over the internet that logs all data transmitted between the two Kissengers (middle).

Design We needed to make Kissenger more usable and robust so that people would be able to use it over a longer period of time. With a help from an industrial designer, we changed the structure, making the base flat so that users would be able to keep it on a surface when is not in use, as shown in Figure 6.8 (left). The size was reduced giving the internal circuitry, battery, motors, and sensors a tighter fit. In order to get the devices to connect over a large distance, we dropped the use of wireless technology and connected the devices to a PC through a USB cable. We developed a Visual C# based program that would allow users to be connected to a server located in our laboratory. The device would send its sensor readings to the server, which would then transmit them to the correct partner as shown in Figure 6.8. The server would also log all transmissions to let us analyze the readings for frequency and duration of the communication. The block diagram of this prototype is shown in Figure 6.9 that illustrates the flow of information when users interact with the device.

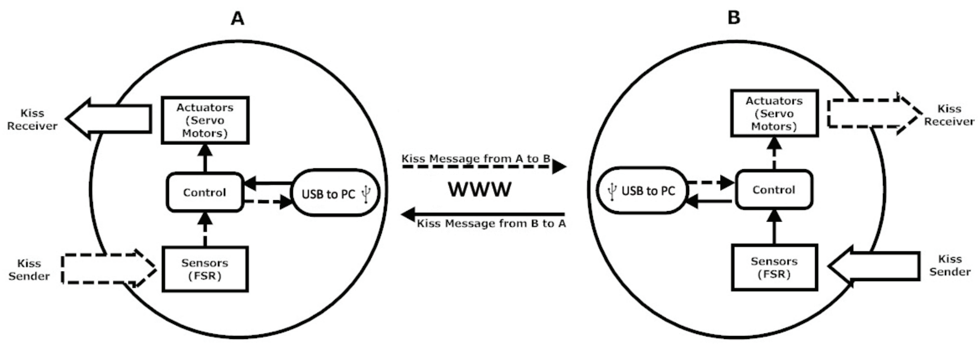

Figure 6.9: Block diagram for the fourth prototype. Dashed arrows show the direction of the sender's interaction from A to B and the solid arrows show the interaction from the opposite direction.

6.2 Field study on the Kissenger

6.2.1 Objective of the field study on Kissenger

The previous evaluation aimed to gather the couples' initial reaction towards the device, to understand its usability and functionality in mediating kiss experiences, and to gather feedback for improvement. However, the results obtained from that user evaluation were insufficient to judge the device's usefulness for intimacy due to it being conducted in a controlled context.

Researchers like [248] and [249] highlighted the importance of measuring the usability of communicative technologies outside the lab, in more realistic situations. The need for designing the study as naturalistic as possible is also emphasized by [250]. In fact, interruptions, movement, noise, and multitasking [251], that could affect the users' performances and evaluations, are not present in laboratory tests. Also, issues such as privacy and adoption can only be evaluated in an environment where people live out their normal lives [252]. Even though there seems to be a common concern about the adequateness of laboratory evaluations, there are few previous projects evaluated in their real usage context and on a longitudinal basis. This may be due to several factors like complexity of the building process (including the robustness and reliability of prototypes) [252] or difficulty of data collection techniques used in the field [253].

In the current study, in order to address the problems in laboratory tests and to develop a better understanding of the influence of Kissenger in supporting remote communication, we conducted a longitudinal field study and explored it under actual everyday situations. It was done in two stages, first in a two weeks time by small sample, where both pairs of users live in Singapore but not living together, and then over a three weeks period with real LDR couples.

6.2.2 Initial field study by small trial sample on the Kissenger

Three young and unmarried romantic couples, with an age in their 20's to early 30's (Mean = 26.67), had participated in the longitudinal field study (as in table 6.2.2) for two weeks. All the participants resided in Singapore but were not co-located with their partner. Educational, professional, and cultural backgrounds were not controlled in this field study due to the small sample size. This small field study was performed to ensure the functionality of the last version of the prototype and fixing the potential issues. Fig 6.10 shows Couple 3 interacting with their devices.

ID	Age (F, M)	Relationship Duration	Usage Frequency
1	22, 26	Two years	2-3 times/day
2	25, 27	Six months	Once a day
3	27, 32	Less than a year	Once a day

Table 6.2: Demographic information and communication habits of three participant couples in the field study

In the first stage of the field study from the pre-interview sessions, some similarities in the remote communication habits were found among these three couples: They all recognized that they're in an early stage of their relationship and have a strong desire to include intimate interactions in their daily life. Most of the remote communication technologies they adapted to facilitate interpersonal communication and intimacy exchange included phone calls and text-based messaging tools (Instant Messaging (IM), short message service (SMS), or social networking sites (SNS)) through ubiquitous technologies. Video calls were recognized as the most effective channel to express emotions and affection between participants, which gives them a stronger feeling of presence-in-absence. They reported using phone calls throughout major breaks during their day such as morning, night, or while eating. During these times, they said they had the most "romantic communication and interpersonal interactions". During the day when they were at work, text-based media, like SMS, were preferred to keep an on-going sense of awareness of the other person, without disturbing other tasks.

It was interesting to see that the usage of Kissenger by the three couples were similar: they interacted in the night before sleeping, approximately around 11 pm to midnight. Only Couple 3 spent some time interacting at noon after lunch. Most of the interactions occurred at their home or in the living room without other people around. It reflects the intimate nature of the device; Kissenger was adopted only during private and spare time. Based on the timing and location of usage, it is obvious that the haptic-based device did not serve to change the communication habit in remote couples, but rather enhanced and reinforced their habits. The haptic interaction in Kissenger contributed to the connectedness of the remote couples, and thus created a special sense of presence-in-absence which is rather different from other visual or audio-based communication tools.

From the subjective responses of participants, in most of the cases, Kissenger was adopted as a complementary channel to existing communication media such as Skype or mobile calling. The interaction with Kissenger was very short during each usage and was used only to "simulate a kiss" during the video or audio conversation. However, most of them did agree that a device involving haptic interactions and vibrations had supported their existing communication media and added a "funny" and "multi-sensory" experience into their video or audio conversations. Similar to the comment from the male participant from Couple 1: *"I think Kissenger can add a fun base to the usage of other face-to-face or voice-to-voice tools"*.

Besides being a complement to support their current communication technology, the device was also found to serve as a trigger for intimate communication after a few days of usage. Couple 3 had such an experience: *"The Kissenger itself now has become a topic of the conversation."* In this way, the pervasive and simple interaction process for Kissenger was able to trigger further and deeper conversations. Although, it should be noted that this statement could be the novelty effect of the technology and might not last in a long term.

According to the feedback from participant couples, most of the users had positive opinions on the concept of the device, and mentioned that it contributed to the connectedness and closeness in their relationship. Even though the mediated kiss experience was not as real and romantic as expected, they were positive regarding the effect of Kissenger in providing a novel "touch" channel and creating presence-in-absence in their remote communication. Some participants stated:

"It's a good social system for couples who live in different countries or far from each other." (Male, Couple 2)

"It is a fun experiment to try out!" (Female, Couple 3)

As the female participant in Couple 2 explained: *"the differences [of Kissenger] from other communication tools are not just to provide a new channel, but also in the unique connection to my boyfriend."* Different from conventional communication tools, Kissenger was not about building mass communication devices for transmitting messages to all kinds of people. Instead, it was to build a specific communication device only for romantic lovers.

As expected, the evaluation in a field study had indicated issues that could never appear in a laboratory test. There were quite a few technical problems discovered in the field study which negatively affected the user experience of Kissenger. As a female participant from Couple 3 stated:

"Server not connected, battery ran out, the device has no response, the transmitted signal cannot trigger the motor. Yes, the fun part is to solve the problems with my partner."

Afterwards, when we were assured that the couple could successfully use the device and we managed to fix a few minor technical issues we moved to field evaluation with real LDR couples.

Figure 6.10: A usage situation of Kissenger in Couple 3.

6.2.3 Main field study on the Kissenger by real LDR couples

In the main field study participants signed up for three weeks of field study. A pre-interview was performed to know the participant, demographic, communication modes, and their intimacy level.

The sample of 10 heterosexual LDR couples (n=20) with a mean age of 26.4 years (SD = 4.60) and age range between 20 to 35 were recruited through social networking websites and by word of mouth. They were intentionally chosen at an early stage of the relationship (less than 2 years), as they will typically be more careful in attending to future outcomes of their relationship and are more concerned with maintaining their closeness and intimacy [254].

Their LDR status selection was based on the self description criteria. There are different perspectives for defining LDR including, defining by physical geography(i.e. partners living in the same city, by being a few nights of the week apart) [255], having separate residences, and self-define (confirmed by themselves) LDR [256]. The self description criterion such as "I consider my relationship to be a long-distance or commuter relationship." are found as the most influential predictor [257, 258]. Therefore, we asked the participants to self define their relationship as LDR by confirming that they cannot see each other face-to face frequently as a result of residential separation.
Moreover, for the final prototype we used USB and connected the devices to a PC, instead of wireless network for more robust communication and minimizing the interference in the experimental context. So, we chose participants who were active computer users both during the work hours and at home. The samples were from different cultural backgrounds and living in different places. The average relationships lengths were 17.6 months (SD=6.5), ranging from 3 to 24 months. The frequency of visits ranged from once a month up to once a year with mean=2.7 and SD=3.27 of visit per year.

Intimacy level was described as one engaged, five committed, three serious, and one casual. The engaged level is defined as officially registered, committed level is defined as faithful and having future plans. Serious level is defined as faithful and feeling deeply in love, and casual level as sharing general information and uncertain about the future. Among all only couple C1 and C3 were sharing financial responsibilities. Demographic information of the participants is described in Table 6.2.3.

ID	**Age(F, M)**	**Place of Residence**	**Relationship Duration in Months**	**Intimacy Level**	**Visit/year**
C1	20,23	Sweden, Malaysia	19	Committed, Share financial responsibilities	1
C2	21,21	Taiwan, Singapore	17	Serious	1
C3	25,27	Spain, Singapore	22	Committed, Share financial responsibilities	2
C4	35,34	Serilanka, Singapore	15	Committed	3
C5	34,26	UK, Turkey	3	casual	1
C6	29,28	Japan, Netherland	10	Committed	1
C7	30,28	Iran, Singapore	24	Engaged	1
C8	22,27	Malaysia, Singapore	20	Serious	12
C9	20,25	Australia, UK	24	Serious	2
C10	24,29	China, Singapore	22	Committed	3

Table 6.3: Demographic information of ten participant couples in the main field study

Participants confirmed they do not plan to visit face-to-face during the time of the experiment. They also confirmed their relationship as LDR. The participants were briefed about the Kissenger usage and the experiment. They were asked to have the robots by their sides while they are communicating with each other through softwares on their computers (i.e video chats) and use it any time that they felt they want to express their love through kisses. To ensure they fully understood the procedure a demo video and written tutorial with one filled diary example was also provided. The participants were provided with contact details of our team to be able to contact us in case they encountered any problematic issue. The participants' efforts were appreciated by a gift set of personalized, paired mugs and shirts for cooperation in the experiment.

Then they received a set of Kissenger and diaries to record their daily experiences. The items were sent by speed-post together with pre-stamped and labeled envelopes to return the diaries. It was designed to explore the impact of Kissenger on the couples' intimate interaction and behavior in the natural and out of the laboratory context. In previous related projects, like SnowGlobe [259] and the VIO system [5], daily documentaries involving a series of quantitative likert scale questions about their relationship status were adapted in the field study. Although these small quantitative surveys were designed to increase the sample size, they did not yield significant results and seemed not particularly useful in understanding how the technology affected couples in practice. It might be attributed to the fact that some daily feelings and experiences are hard to be reflected and observed by quantitative methods.

Consequently, the daily documentary in this user study focused on qualitative open-ended questions, which guide couples to record their everyday usage and experience of Kissenger. It encourages participants to release more subjective and unexpected experiences through verbal description. Other formats of recordings, such as photos, sound or even video, were allowed in order to complement the text-based storytelling and help towards discovering different dimensions of the effect of the device on their relationship and intimate communication. The participants were asked to log their daily experiences latest by the beginning of the next day, so that experiences could be still recalled. We used the *time and event-based* method [260] with the Kissenger usage, as the event triggering factor. Some hints were provided for participants to narrate their experiences. Such as: Description of the scenario that they used Kissenger, usage context, perceived feeling, expectations and issues they encountered.

Complementary to the self-report data, the events of user-device interactions are logged in the system. This is done to obtain objective quantitative measures of user-device interaction behavior. For each participant, the dataset includes a) frequency of use, i.e. times and duration of each use; b) situation of use, i.e. timing and whether the interaction was mutual or not.

Follow up interview: After the experiment a 30 minute post-interview and debriefing session was held within one week from the end of the field study. The couples were contacted and interviewed separately. The post interview questions were structured with the intention to find out more about the user experience and overall reactions to Kissenger, and if use of Kissenger yield any considerable effect on the participants' communication: Such as: Whether they felt Kissenger was able to improve their current communication habit or not. Whether they would like to augment Kissenger in their communication device or not? If not, what changes they require to use it?

6.2.3.1 Analysis and results of the Kissenger field study

The interview data were recorded and transcribed. The interview data together with diaries were coded and analyzed using models introduced in [261]. The method involved mining the key themes, and categorization to uncover patterns and similarities by looking at recurring categories. These captions could allow a deeper understanding of the underlying motives and effects of interactions on mediating intimacy.

A total of 397 experience diaries were collected during the three weeks of study (few of the daily experiences were not filled). The collected data were analyzed based on qualitative content analysis [1], which involves categorizing the data and then studying the frequency of category occurrences. Content analysis is chosen since in our study coding categories will be inferred directly from the text data [263]. In the diaries, hints were provided to help participants to express their experiences, but no pre-existing theory exists and we were also open to unexpected themes. Therefore, conventional content analysis is appropriate for this study [264]. We applied open and axial coding to transform the collected data into quantitative data.

In the open coding stage, all the transcripts were read and words related to

[1]Content analysis is a research methodology for making replicable and valid inferences from text and other media to the contexts of their use [262]

the users perceived and expected experience were highlighted. The highlighted words were chosen as code based on the participants' words with the goal of defining key themes without any predefined class. As a result, 40 loosely related codes pointing to about 650 instances of the data emerged.

Afterwards, axial coding was performed. In axial coding related open codes were put together and classified into 10 main categories pointing to features such as: appearance, functionality, intuitiveness, etc. as described in table 6.2.3.1.

Open Codes	**Axial Codes**
Size, Shape, Facial features, Material, Appearance	Aesthetics
Actuations, Real-time-ness, Responsiveness, Noiseless	Functionality
Learnability, Immediacy, Familiarity, Simplicity	Intuitiveness
Convenience, Flexibility, User Friendly, Concision	Ease of use
Personalized, Customizable, One-to-One, Possession	Uniqueness
Anthropomorphic, Embodied, Multimodal, Simultaneous	Multisensory Communication
Portable, Wireless, Lightness	Mobility
Intensity, Haptic stimulation, Realness, Texture	Naturalness
Encoding, Hiding, Embarrassment,Cultural Reaction	Privacy
Enjoyment, Serendipity, Joint configuration, Entertainment	Joy of co-experience

Table 6.4: Open and axial codes resulted from content analysis

Quantitative analysis: All the transcripts and diary data were categorized initially as being tied with one of the 10 themes. This process was done by the author and her colleague, who was also involved in the axial coding (coder reliability kappa=0.89); disagreements were settled by discussion. The distribution of the collected data over the three weeks duration of the study were identified for each of the 10 themes.

According to the derived temporal pattern and the collected semantic data, the 10 themes were distributed in 2 main adoption phases of familiarization and incorporation, which are described below:

6.2.3.2 Familiarization

Familiarization reflects to the first experiences that were due to the intense emotional reaction to a new technology such as pleasures, annoyance, cultural reactions, and the configuration and learning issues which decreased drastically after three days of usage.

Positive feedbacks (N=28), reflecting emotional reactions caused by Kissenger's aesthetics (N=10) , joy of co-experience (N=6), and the serendipity of mediated kiss (N=12), and (N points to the number of words). Below are some of the positive feedbacks

[Aesthetics day 1] *"When I received the package and opened it, I said to myself: OMG this is so cute!"*.

[Joy of co-experience day1], *"The first time we decided to use Kissenger, we had no idea how to install it. Together with my partner, we read the given instruction and could finally set it up. It was a good experience to get something work together while we were apart."*

[Serendipity (Joy of co-experience)day2], *"Once we kissed each other by Kissenger interface, we laughed a lot because we suddenly heard an unexpected sound of* *motors which was funny. The fact that such cute and funny gadget could make us laugh together was very interesting and motivated us to use and enjoy."*

Negative feedbacks (N=15) reflected the acceptance of the mediated kiss and was related to the cultural reaction to the radical nature of the Kissenger interactions. An example is presented below:

[Cultural reaction (privacy) day3], *" For some unknown reason, I was feeling guilty kissing a robot and suggested my partner, to stop using it. This sparked a conversation between me and my partner, but at the end, we were convinced that there is nothing wrong. I could consider Kissenger as a tool to reach to my partner, not a kiss machine"*

Table 6.2.3.2 summarizes the results of familiarization phase:

<table>
<tr><th>Category</th><th>Theme</th><th>Examples</th></tr>
<tr><td rowspan="3">Positive Reactions (N=28)</td><td>Aesthetic (N=10)</td><td>This is so cute</td></tr>
<tr><td>Joy of co-experience (N=6)</td><td>Enjoyed configuring the system together</td></tr>
<tr><td>Serendipity (N=12)</td><td>The unexpected sound of the motors made them laugh</td></tr>
<tr><td>Negative Reactions (N=15)</td><td>Cultural Reaction (N=15)</td><td>Initially felt guilty using Kissenger</td></tr>
</table>

Table 6.5: Content analysis results in the familiarization phase in the first three days

6.2.3.3 Incorporation

The incorporation phase reflects how Kissenger became purposeful and was practically used in context of the daily life. All the participant found it meaningful after 3 days and incorporated using Kissenger on a daily basis.

Positive feedbacks (N=64) reflected design features that support Kissenger meaningfulness over time. Including Kissenger temporal usability (N=22), describing how Kissenger was practically used, whereas, affectivity (N=42), reflects how Kissenger could trigger and express emotions.

In relation to temporal usability, functionality (N=7) and intuitiveness and ease of use (N=15) were mentioned. Narrations related to affectivity pointed to the appearance (N=9), joy of co-experience (N=15), uniqueness of communication channel (N=10), multisensory connection (N=8). Below are several examples:

[Functionality, day 2] " *The possibility of synchronous kissing makes it more similar to the real kiss. In reality, when we kiss we need to feel the feedback immediately. Kissenger helps to get the feedback quickly. It is much better than sending emoticons or just type the word kisses and wait to see the answer."*.

[Intuitive and ease of use, day 5] " *It was very convenient to kiss my partner with Kissenger. I was eating my breakfast and at the same time talking to my boyfriend on Skype, I kissed him without any need to touch the keyboard and type anything. I simply kissed him using my lips. I enjoyed the convenience."*.

[joy of co-experience, day10] " *It was entertaining to use Kissenger. It was more than just kissing. The experience of playing with Kissenger together at the same time was a joy.*".

[Uniqueness of communication channel, day 19] " *The thing I liked about Kissenger is that, it is used only for kissing between me and my girlfriend. Skype also has kiss emoticon, but having something exclusively for her is a different feeling. It feels good, recently, sometimes even just looking at the gadget reminds me of her.*".

[Multisensory connection, day 15] " *Kissenger, gave us the chance to be connected by touch of the lips. It makes me feel I am not simply talking to a face in the laptop, So it felt more real.*".

[Appearance, day 17] " *I came home from shopping, went to my room and then saw the Kissenger on my desk. It reminded me to have a talk with my partner. I felt it was a nice idea to have a tabletop device in front of my eye that triggered us to communicate.*".

There were also some experience narrations in the diaries that reflected negative feedbacks (N=73) related to temporal usability (N=42), and, affectivity (N=31), which were not considered in the design.

[Temporal usability, day 6] " *I was waiting for the bus at the bus stop, and at the* *same time talking with my partner on the phone, though, since it was not easy to carry along the Kissenger, we missed the chance of kissing via Kissenger. It was disappointing that Kissenger was not portable.".*

[Temporal usability, day 14] *" I was Skyping with my girlfriend in my office but we didn't kiss, I felt it was embarrassing if someone sees me kissing a device. I wish it was designed differently so that I could use it in public as well.".*

[Affectivity, day 15] *" Kissenger lip material is a bit hard. If it was made form fur or something softer it was much more expressive."*

Table 6.2.3.3 summarizes the content analysis results in the incorporation phase.

Category	**Theme**	**Subclass**
Positive Reactions (N=64)	Temporal Usability (N=22)	Functionality (N=7)
		Intuitiveness and ease (N=15)
	Affectivity (N=42)	Shape and appearance (N=9)
		Joy of co-experience (N=15)
		Uniqueness (N=10)
		Multisensory connection (N=8)
Negative Reactions (N=73)	Temporal Usability (N=42)	Privacy (N= 8)
	Affectivity (N=31)	Naturalness (N=10)

Table 6.6: Content analysis results in the incorporation phase of the Kissenger

6.2.3.4 Interview results

An analysis of the post-experiment interviews, indicated that at least 15 out of 20 participants found that Kissenger could potentially improve their communication habits.

They reflected this indirectly in terms of physical connections, private channel, expressiveness and enjoyment. Also four of the couples asked if they could keep Kissenger and use it in the future.

We also were interested to know what changes the participants prefer to be done in Kissenger. The answers could be classified into the themes of initiations (N=6), portability (N=10), usability in public (N=7), association (N=4), the lips realness (N=7), and realtimeness (N=5). The distribution of the codes associated with required improvements is illustrated in table 6.2.3.4

Initiation pointed to the need of the participants to implicitly initiate the kiss by means of body languages and eye contacts rather than through verbal language such as saying "let's kiss now."

Portability was another expectation of the users. They would rather be able to have the Kissenger all the time and use it in their convenience rather than only when they were in front of the computer.

Another group of repeated words pointed to the need for the possibility of using Kissenger in public. Participants found it embarrassing to be used in public. Association was also a theme of answers which reflects the need of having features in Kissenger, which make it similar and related to their remote partner such as its appearance. In relation to the realness of the lips, participants suggested to use a soft and skin like material. And finally, delays in transmission of the kiss compared to real kiss, which is caused by the barrier of the media was another issue which needs improvement.

Theme	N	Explanation
Initiations	6	Facilitating natural way of initiation such as eye contact
Portability	10	Smaller or wearable designs such as accessories
Usability in public	7	A design that does not attract the attention of outsiders
Association	4	A relation between remote partner and the kissenger appearance
Realness of lips	7	Use of soft or skin-like material
Delays	5	Delays should be minimized as much as possible

Table 6.7: Suggested improvements on Kissenger revealed during the interview

6.2.4 Discussion and design lessons

Overall, we found that the factor of time could affect the perception of the participants. We found two different stages of familiarization and incorporation. In the familiarization stage the emotional reactions were more intense and were mainly focused on serendipity, configuration, cultural reactions and aesthetic. After three days, the theme of feedbacks changed and the focus was mainly around the usability and affectivity of Kissenger. This findings are in line with the previous research on temporal study of user experience and adaptation to social and physical context[265, 266].

The design exploration on the Kissenger gave us many design insights. For instance, in relation to the need for association with the partner, one idea to make each device more customized is to design a simple model with accessories that can be removed and attached in a number of ways.

Also, to support usage in public, we have also thought about adding a symbolic emotional communication feature. Many people use 'kiss', 'xoxo', or ':-*' emoticons in their chat, email or text messaging to represent a kiss. These characters are very common in text based communication methods between partners. Similarly, we could develop symbolic representations for Kissenger. For example 'XXXXXXX' may refer to a very tender long kiss while 'X' may refer to a quick kiss.

This leads to another question that we have considered, asynchronous kissing which is the ability for the device to store a kiss that can be read at a later time. This feature opens up a lot of potential ethical issues from the design of Kissenger, which is discussed in the next paragraph.

Apart from questions relating to interaction, Kissenger raises a number of ethical questions. In an affirmative sense, this device could be seen as a basis for positive affection towards society. As this system could be used to transfer emotions to loved ones, especially between parents and children, it will bring physical comfort and satisfaction which is a vital need for young children when their parents are far apart.

Couples that use this device for a longer period of time may suffer from a lack of real physical affection. There also might be social ramifications for failing to return a kiss from a partner received offline on Kissenger. On the legal front, these devices also open a debate related to aspects of adultery in relationships.

For example, would usage of the device with another person constitute infidelity by the partner?

6.2.5 Summary

In this exploratory study, we presented our study on mediating intimacy through the design and evaluation of Kissenger, an interactive device that provides a physical interface for transmitting a kiss between two remotely connected people. We described our design process through four iterations where each stage had a separate focus. Our field study suggested the possibility of meaningfulness of the Kissenger in the daily life of the remote couples. The result of this chapter has addressed the need for development and in depth analysis of telepresence technology for communication of the kiss which was pointed as "research problem 2" in section 1.2.

Of course the study of mediated kiss is still in its infancy and still more research is needed to satisfy the users. The iterative design process has highlighted potential design pitfalls that designers should be aware of when making similar devices. We hope that this kind of research will enable a new dimension for remote couples to interact, in addition to enhancing existing communications by adding the under-used sense of touch.

Chapter 7

Summary and Conclusion

7.1 Research summary

This dissertation has taken steps towards the futuristic aim of teleporting the presence of an intimate partner. In this spirit, three different aspects of intimacy, including cognitive, emotional and physical, within LDRs (long distance relationships) were explored. The focus of the study has been on modeling new telepresence media through simulation and physical prototyping. Moreover, the study has mainly focused on connectedness-oriented communication, in which maintaining relationships and fostering a sense of connectedness is the core of the interaction, but not the awareness.

The iterative multilevel modeling methodology (3.2) was applied to address research problems with the outside inwards hierarchy. Initially, the focus was on the form factor and the body of the agent. A pair of personalizeable humanoid telepresence robot was proposed as the medium of the interaction. The study then evolved towards development of a smartphone based AI model for intimate telepresence. This attempts to address emotional telepresence specially for off-line mode. Afterwards, a haptic telepresence system was developed to teleport kisses and support physical intimacy.

In the first step, application of personalized humanoid robots for intimate telepresence was explored. The focus was on the design, prototyping and experimenting the effect of personalization on the perceived affectivity. Physical embodiment, and anthropomorphism in humanoid robots facilitate communicating nonverbal signals associated with intimacy, which are overlooked in virtual (non-physical) media. To address this issue, the idea of using embodied media as the surrogate of the absent partner is explored. As a result a pair of low cost prototype was developed as a platform for physical telepresence with intimate partner. Also, it was found that robot personalization could have a positive effect on the perception of affectivity. The Effects of personalization on user perception is widely supported by researchers focusing virtual avatar applications, such as games and second life [163, 164, 165]. That is also in agreement with the theory of enclothed cognition [187]. The perceived affectivity can be due to the attribution to the user (remote partner), which is one of the parameters contributing to the intimate presence (5.2.2). Moreover; the developed minimal prototype acted as a tool to facilitate brainstorming and inferring the user's expectations from humanoid telepresence robots. The feedback results could act as a design guideline for interactive media developers in the field of intimate computing.

It is acknowledged that due to the multidisciplinary nature, technical challenges and implementation costs of the high fidelity humanoid telepresence systems, studies on these sort of telepresence systems are still in infancy. Direct collaboration with industry is needed to achieve the ultimate goal of recreating the holistic presence of a remote user. Further research is needed to extend the minimal viable prototype to fully embodied telepresence system. Real-time projection of the users face on the curved screen for transmitting facial expressions as well as eye gaze direction, multisensory feedbacks from the robot, more degree of freedom of the robot body, minimizing the robot size, and predictive models for real time channeling between the remote user's behavior and its surrogate are examples of future research direction.

From the previous step, it was learnt that control mechanism of the proposed telepresence robots needs to be improved. One reason for this decision was maximizing the intuitiveness and opportunities of the connectedness by automatic behavior generation. Gesture recognition based approaches for telepresence, besides their challenges in robust recognition can only work in online mode. To afford connectedness in off-line mode where both users cannot be simultaneously available an AI model was developed. The model has focused on communicating based on the affective state of each user; however, it could be applied to broader areas of experience sharing such as activity-based communication. The developed model is a combination of DBNs and behaviors networks. The model can estimate the probabilistic mood state of the users and control their stand in agent accordingly. The model was tested through a developed smartphone app simulator. The system was tested in scenario based interaction with the user. The result showed that the system could perform well and facilitate a connectedness oriented interaction. It should be noted that the model has some limitations. Firstly, the developed model is probabilistic in nature. Therefore, it cannot be used as an awareness system. Secondly, the model is designed for active smartphone users, hence, it cannot be relied on for users who do not constantly interact with their smartphones. Further research is needed to infer the highly accurate high level state of the users.

Finally, in the third step of the research, teleporting physical intimacy in LDR was explored. The focus of the study was on the design and develop of an embodied media to transmit kisses across distance which is referred to as Kissenger. The Kissenger is designed for couples in LDR to facilitate physical intimacy across distance. Kissenger was developed within four main iterations, which progressed from concept evaluation to physical properties, then to the kiss properties and eventually to user adoption. In the first phase, a lifelike lip surrounded by minimalistic shape was prototyped, and the user feedbacks were collected during a focus group study. The most important feedback was the lack of the personality and creepy design. This result is in line with the uncanny valley [96] and the similar result was achieved in previous similar works such as intimate mobiles [97], and haptic creature[267].

Armed with the results attained in the first iteration the second iteration was developed. A second prototype was decided and evaluated during the focus group with lab members not involved in the project. The main required improvement in this stage was towards the quality of the lips and the interaction. The more naturalistic interaction could improve the perceived experience. In the third iteration, a paired set of Kissenger was built with more attention to the lip material and kiss sensation. The third version was evaluated and a comparison between communication through Kissenger augmented on Skype and Skype alone was performed. The objective of our experiment was twofold. Firstly, we wanted to test whether using a mediated kiss device such as Kissenger enhances the affectivity of communication compared to common affect expression methods in telecommunications such as emoticons for text or audio-visual affect expression. Secondly, we wanted to inspect the role that Kissenger has in fostering the sense of co-presence; when the remote user is kissed by the partner using the device, to what extent is the illusion of being together conveyed? The results showed similar experiences for both scenarios ($t(13) < 1.99, n.s.$) with the exception of two affectivity questions, "Does communication through this interface create an intimate experience?" and "Was the received kiss similar to a natural kiss?" for which a paired two-tailed t-test revealed that Kissenger received a significantly higher score ($t(13) = 4.59, p < 0.01$) and ($t(13) = 2.24, p < 0.05$) respectively. These results are consistent with our design goals. Users explained that the physical interaction with the device was analogous to the interaction one might have with their partner. These findings suggest that the physical interaction with Kissenger increase the emotional engagement with the device and the partner. Kissenger uses wireless technology to transmit the digital equivalent of a kiss. There are some important conditions necessary to appreciate the experience of this prototype: an intimate relationship, two distant people, and a method used to synchronize the time of the kiss such as a phone call or video chat. The two prototypes that were made for the user study were not as robust and reliable as we had imagined. Towards the end of the evaluation, the connection between one servo motor and the lip slipped out, requiring researcher intervention. The placement of the heavier components of the circuit was not optimal, making the Kissenger roll towards its center of mass near its mouth whenever it was placed on a flat surface. We created holders for these devices for the evaluation as a work around. Both these issues were solved in the next revision with better industrial design. We needed to make Kissenger more usable and robust so that people would be able to use it over a longer period of time. The Kissenger should be also evaluated in the context of daily life and outside the lab environment with real LDR couples.

The importance of measuring the usability of communicative technologies outside the lab, in more realistic situations highlighted by other researchers such as [250]. In fact, interruptions, movement, noise, and multitasking, that could affect the users' performance and evaluation, were not present in laboratory tests.

Besides, issues such as privacy and adoption can only be evaluated in an environment where people live out their normal lives [259]. Even though there seems to be a common concern about the adequacy of laboratory evaluations, there are few previous projects evaluated in context and on a longitudinal basis. This may be due to several factors like complexity of the building process (including the robustness and reliability of the prototype) or difficulty of data collection techniques used in the field. In order to address the problems in laboratory tests and develop a better understanding of the influence of Kissenger in supporting remote communication, we conducted a longitudinal field study and explored it under actual everyday situations over the three-weeks period. According to the derived temporal pattern and the collected semantic data, the 10 themes were distributed in two main adoption phases of familiarization and incorporation. Familiarization reflected to the first experiences that were due to the intense emotional reaction to a new technology such as pleasures, annoyance, cultural reactions, and the configuration and learning issues which decreased drastically after three days of usage. These findings are in line with the previous research on the temporal study of the user experience and adaptation to social and physical context. The design exploration of the design of the Kissenger and the previous study of the mini-surrogate robots gave us many design insights. For instance, in relation to the need for the association to the partner, one idea to make each device more customized, is to design a simple model with accessories that can be removed and attached in a number of ways. Moreover, to support the usage in public, we have also thought about adding a symbolic emotional communication feature. The iterative design process has highlighted potential design pitfalls that designers should be aware of when making similar devices.

The study of mediated kisses is still new and still more research is needed to be widespread. We hope that this kind of research will enable a new dimension for remote couples to interact, in addition to enhancing existing communications by adding the under-used sense of touch. Further research is therefore needed to reproduce the natural sensation of the remote kiss without falling in the uncanny valley. Also, this study has studied kiss mainly from the perspective of a haptic interaction. Although, other nonverbal cues such as eye contact for initiation of the kiss, hugs, smell and many more are usually communicated at the same time, which requires more research.

7.2 Research Directions and Recommendation for Future Studies

The field of intimate computing is largely populated by technologies that intend to facilitate experience sharing. However, they tend to have likeness and monotony and provide very naive approach to love and relationships [74]. Therefore, technologies and design ideas that support different love languages with more subjective nature are needed. Also a well structured design framework potentially facilitates empirical evaluation and interpretation of the effects.

Moreover, the Study of unmediated intimate communication reveals unmet research questions. For instance an interesting question is whether people hold the same expectations about the use of mediated intimacy as about the unmediated one. In the other word whether or not the mediated communication has the same physiological and psychological effects.

Another research question could be the cultural differences and their perceived effect. In real-life scenarios, people have different reactions to the opposite sex and to their own partner compared to the same sex and to strangers. Exploring the design solutions and engineering ideas that recreate the same sensation in mediated environments is also recommended.

Besides current technologies still do not support the same natural sensation of real intimate communication. Studies on real interaction offers a good solution to explore the necessary technical and design improvements. Experimental studies on physical properties of real intimate interactions could help to figure out the physical properties (e.g., required actuation amount, pattern) which may lead to more organic sensation.

Exploration of alternative solutions with the same physiological or perceived effect instead of literal simulation of intimate behaviors is suggested. For instance, approaches such as rubber hand illusion [268] could be adapted to provide the perception that the medium acting on behalf is the extension of self.

Also physical close interactions cause the release of chemicals such as oxytocin and serotonin that help people to feel happy and connected [269]. Studies on alternate technologies that stimulate the brain for the same reaction could contribute to this field. Also, since the nature of this study is multidisciplinary, involvement of people from different fields can be promising.

Although in real physical intimate expressions the communication channel is usually human skin, none of the mediated intimate behaviors have used the texture resembling skin, or flesh to flesh contact. The reason is commonly justified as avoiding the uncanny valley [96]. Intimate computing researchers are in the dilemma of creepiness on one hand and the potentially rich, high fidelity telepresence on the other hand. Solving this issue can be one future research focus as well [97].

In intimate communication systems, there is a move towards investigating the use of touch. In the current systems, it is usually done through simple vibration, pressure or other forms of actuation. Development of high fidelity mediums through advanced control of tactile stimulation algorithms, non-invasive sensing technologies or machine learning is still needed.

Current telecommunication mediums such as video conferencing compromise the non-verbal signal of eye-gaze direction. Although there has been very few attempts in this area [270] they are still in their infantry. Technical improvements and integration with intimate computing interfaces could be promising.

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Appendices

Appendix A

Questionnaires and User Study Materials

Mini-Surrogates affectivity questionnaires

Age:

Gender:

Duration of the relationship:

Maximum duration been apart:

Please answers the following questions, considering 1 represents the lowest extend and 7 represents the highest extend:

- I enjoyed interacting with my partner through the robot

  ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

- I enjoyed the conversation with my partner through the robot

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- I feel I could communicate with my partner expressively

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- The robot helped to enhance the quality of the communication

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- During the interaction robot could facilitate an emotional experience

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- The interaction seemed natural to me

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- To what extend you could imagine the robot to be your partner

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- How do you rate your willingness to communicate this way

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- To what extend you felt the appearance of the robot was likeable

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- To what extend you were satisfied with the experience

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- To what extend the robot reminded you of your partner

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- To what extend you feel you would like touching and hugging the robot

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- To what extend the robot seemed friendly to you

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- To what extend you felt like having eye contact with the robot during the conversation

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- To what extend you liked the robot

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- To what extend the interface was appealing to you

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

Open-ended questions:

What was your overall perception on the quality of the interaction?

Please write any suggestion that you wish to make about your experience? What modifications you suggest to improve the system?

Kissenger lab experiment questionnaires

Affectivity questionnaires:

- Was the received kiss similar to a natural kiss

  ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

- Does communication through the interface create an intimate experience

  ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

- Does the interface enhance your relationship even though you were remote

  ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

- Can you express your affection through this interface

  ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

- Did you enjoy the experience of kissing your partner through the interface

  ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

- Did you enjoy the experience of being kissed by your partner through the interface

  ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

Co-presence questionnaires:

- To what extend if at all, did you have the sense of being in a same place

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- To what extend if at all, robotic interface was blurred and you had the perception of kissing your partner

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- When you think back about your experience to what extend you remember this as kissing your partner rather than interacting with an object

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- To what extent were you aware of your partner's presence

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

- Overall rate the degree to which you had the sense of being with your partner rather than only a device

  □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7

Kissenger field study materials:

Daily experience documentary For long term user study

Couple ID:

Gender:

Age:

Length of Relationship:

Country of residence:

Level of intimacy:☐ Engaged ☐ Committed ☐ Serious ☐ Casual

Do you share financial responsibilities: ☐ Yes ☐ No

Usage period:

Post Interview date:

Note:

Please take care of the device. Shift off the vibration after every time interaction to save power.

Please record the your experience in this documentary

You are recommended to take some photos of the using situations to explain the experience (or in other format, like sounds or video, depends on your availability)

If you have any problems or questions during the usage period, please contact Elham at 92992340 or elham@nus.edu.sg

Process to set-up the Kissenger:

1. Open the file “chatclientsetup”;
2. Check “set-up”.

Use of Kissenger:

1. After installation, check ’chat client’;
2. In the window of ’chat client’, serve IP is ’137.132.145.91’;
3. We will provide you a ’Port’ number and ’COM port’ number. It will remain there every time you use it;
4. Input your name, check connect;
5. Turn on the vibration function of Kissenger and interaction with you partner. You will be also informed the status of the kiss.

Daily diary hints:

1. How many times you interact with your partner today?
2. How many times you use Kissenger today?
3. Under what situation you use it (when and where, what topic of the conversation or interaction)?
4. The context you want to use it in. What make you want to use it in the conversation or interaction with your partner? (considering this by comparing with other remote communication tools like IM, email, skype)
5. What was your experience in using it? (For e.g. Positive or Negative? How did you feel? Did the device contribute to the conversation? If yes, how? If no, why not?)
6. Were there any situations in which you decided not to use it? Please elaborate on some possible reasons.
7. Additional comments (do not necessarily have to cover today's conversation)

Follow up interview questions:

Do you feel that Kissenger was able to improve your communication habit or not?

Would you like to augment Kissenger on your communication medium or not?

What changes you suggest to improve the system?

Appendix B

List Abbreviations

Abbreviation	Description
AI	Artificial intelligence
AST	Affective State Transition
CMC	Computer - Mediated Communication
BN	Bayesian Network
DBN	Dynamic Bayesian Network
FKCN	Fuzzy Kohonen Clustering Networks
F2F	Face - to -Face
GPS	Global Positioning System
GUI	Graphical User Interface
HCI	Human - Computer Interaction
HMD	Head Mounted Display
HRI	Human - Robot Interaction
ICT	Information Communication Technology
LDR	Long - Distance Relationship

Abbreviation	Description
LED	Light - Emitted Diode
MVD	Minimum Viable Prototypes
P	Probability
PME	Probabilistic Mood Estimation
RFID	Radio - frequency identification
RTV	Room Temperature Vulcanization
SAM	self Assessment Manikin
SD	Standard Deviation
SVM	Support Vector Machine
WoZ	Wizard of Oz

Appendix C

Publications

C.1 Main publications:

1. Saadatian, E., Samani, H., Parsani, R., Vikram Pandey, A., Li, J., Tejada Rodriguez, L., ... and Nakatsu, R. (2014). Mediating Intimacy in Long-Distance Relationships Using Kiss Messaging. International Journal of Human-Computer Studies. Pages 736-746

2. Saadatian, E., Samani, Nakatsu R. (2015) A longitudinal Field Study on Kiss Mediation Interface for Long Distance Relationships, To Appear In Proceeding of 17th International Conference on Human-Computer Interaction, HCII 2015 Conference. ACM.

3. Saadatian, E., Salafi, T., Samani, H., Lim Y., Nakatsu R. (2014) Artificial Intelligence Model of Smartphone-based Virtual Companion, In Proceeding of Entertainment Computing, ICEC 2013 Conference. Springer Berlin Heidelberg.

4. Saadatian, E., Samani, H., Fernando, N., Polydorou, D., Pang, N., & Nakatsu, R. (2013, September). Towards the Definition of Cultural Robotics. In Proceeding of IEEE International Conference on Culture and Computing (Culture Computing), 2013 (pp. 167-168).

5. Saadatian, E., Salafi, T., Samani, H., Lim Y., Nakatsu R. (2014) An Affective Telepresence System Using Smartphone High Level Sensing and Intelligent Behavior Generation. In Proceeding of International Conference on Human Agent Interaction. ACM.

6. Saadatian, Samani, H., Nakatsu R. (2014) Anthropologically Inspired Creative Design for Intimate Telepresence. In Proceeding of International Workshop of SIGGRAPH ASIA 2014 . ACM.

7. Saadatian, E., Hariri, R., Cheok A.D, Nakatsu R. (2014) Development of Smart Infant-Parents Affective Telepresence System. In Proceeding of International conference on Human Agent Interaction. ACM

8. Saadatian, E., Samani, H., Vikram, A., Parsani, R., Tejada Rodriguez, L., & Nakatsu, R. (2013, August). Personalizable embodied telepresence system for remote interpersonal communication. In proceeding of IEEE RO-MAN, 2013 (pp. 226-231).

9. Samani, H., Teh, J., Saadatian, E., & Nakatsu, R. (2013, February). XOXO: Haptic interface for mediated intimacy. In Proceeding of IEEE International Symposium on Next-Generation Electronics (ISNE), 2013 (pp. 256-259).

10. Saadatian, E., Samani, H., Toudeshki, A., & Nakatsu, R. (2013). Technologically Mediated Intimate Communication: An Overview and Future Directions. In Proceeding of Entertainment ComputingICEC 2013 Conference (pp. 93-104). Springer Berlin Heidelberg.

11. Samani, H. A., Parsani, R., Rodriguez, L. T., Saadatian, E., Dissanayake, K. H., & Cheok, A. D. (2012, June). Kissenger: design of a kiss transmission device. In Proceedings of the Designing Interactive Systems Conference (pp. 48-57). ACM.

C.2 Under review publication

1. Saadatian, E., Samani, H., Nakatsu R., An Automated Affective Behavior Generation System Using Smartphone High Level Sensing for Intimate Telepresence, IEEE Systems Journal, Dec. 2014 (Submitted)

C.3 Other publications:

1. Samani, H., Saadatian, E., Jalaeian E. (2015) Biologically Inspired Artificial Endocrine System for Human Computer Interaction, To Appear In Proceeding of 17th International Conference on Human-Computer Interaction, HCII 2015 Conference. ACM Digital Library.

2. Samani, H., Saadatian, E., Pang, N., Polydorou, D., Fernando, O. N. N., Nakatsu, R., & Koh, J. T. K. V. (2013) CULTURAL ROBOTICS: The Culture

of Robotics and Robotics in Culture. International Journal of Advanced Robotic Systems, Pages 212-222

3. Toudeshki, A., Mariun, N., Hizam, H., Wahab, N. I. A., Hojabri, M., Said, Y. A., ... & Saadatian, E. (2013). Derivation of Load Peak Voltage, Power Consumption and Potential Energy Management in a Thyristor Controlled Marx Impulse Generator for Capacitor Discharge Application. Majlesi Journal of Energy Management, 2(2), Pages 22-27.

4. Samani, H. A., & Saadatian, E. (2012). A Multidisciplinary Artificial Intelligence Model of an Affective Robot. International Journal of Advanced Robotic Systems, 9, Pages 153-163.

5. Samani, H. A., Koh, J. T. K. V., Saadatian, E., & Polydorou, D. (2012). Towards robotics leadership: An analysis of leadership characteristics and the roles robots will inherit in future human society. In Proceeding of Intelligent Information and Database Systems (pp. 158-165). Springer Berlin Heidelberg.

6. Saadatian, E., Iyer, S. P., Lihui, et. al (2011, December). Low cost infant monitoring and communication system. In Proceeding of IEEE Colloquium on Humanities, Science and Engineering (CHUSER), 2011 (pp. 503-508). IEEE